#45

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163 ADELINE STREET · OAKLAND 20, CALIFORNIA

12/28/67 DLC

MODEL 139

PULSE GENERATOR

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I CHARACTERISTICS

1. FEATURES

The E-H Model 139 Pulse Generator is designed for maximum utility--but what the specifications don't state is that the Model 139 features:

Open-circuit and short-circuit proof output

Minimum of internal adjustments

Non-interacting controls

All solid state circuitry

Reliability and stability

In addition, the Model 139 will provide duty cycyles greater than 90% by simply inverting the pulse output.

2. PULSE REPETITION FREQUENCY
1 kc to 20 Mc

Internal: The internal clock repetition rate is continuously variable from 1 kc to 20 Mc. Range selection is in 1 - 3 - 10 sequence with continuous fine control.

External: With external triggering, pulse repetition rate may be varied from zero to 20 Mc.

3. OUTPUT PULSE AMPLITUDE
±10 volts into 50Ω

The Model 139 will provide 10 volt pulses of either polarity into a 50Ω load. Amplitude is continuously varaible from less than ±3 volts to ±10 volts.

An output attenuator provides range control in 1 - 3 - 10 sequence. Continuous output is available from ±30 mv to ±10 volts.

4. RISE AND FALL TIME
6 ns to 100 μs

A range selector switch provides pulse rise and fall time control in 1 - 3 - 10 sequence from 6 ns to 100 μs. Independent vernier control is provided, which permits as much as 3:1 difference between rise and fall times.

Rise and fall time linearity specifications imply that the rate of voltage change with time is essentially constant; i.e., dV/dt = constant. Non-linearity is less than ±5% on all ranges; from 300 ns to 100μs it is less than ±3%. For a concise definition of non-linearity, refer to page 19, paragraph 4C.

5. PULSE WIDTH
20 ns to 300μs

Pulse width is variable from 20 ns to 300μs with range selection in 1 - 3 - 10 sequence. A vernier provides control in each range with 5% overlap to adjacent ranges.

6. PULSE DELAY
50 ns to 100μs

Delay between the trigger and output pulses is variable from 50 ns to 100μs with range selection in 1 - 3 - 10 sequence. A vernier provides continuous control in each range with 5% overlap to adjacent ranges.

7. PULSE POLARITY
positive or negative

There are 4 output pulse modes available:

1) Positive Normal

2) Positive Inverted

3) Negative Normal

4) Negative Inverted

8. DUTY CYCLE
50%

If the width or delay is extended beyond the duty cycle limit, the repetition rate will scale down in frequency, assuring complete overload protection. Duty cycles greater than 90% may be obtained by simply inverting the pulse with the POLARITY selector switch.

9. SYNCHRONOUS GATE
-2 volts; -15 volts

This design feature applies the gating signal to the repetition rate multivibrator; since the gating signal initiates the pulse train, it is in perfect synchronism. $Z_{in} \cong 300\Omega$

10. WAVEFORM

Pulsetop distortion is less than 5% peak-to-peak for pulse amplitudes greater than 3 volts. This figure is for all pulse top anomalies including ringing, overshoot, droop, etc. Baseline distortion is also less than 5% peak-to-peak, except for 100:1 attenuation, in which case it is less than 8%.

11. JITTER
0.1% ±50ps

This figure includes repetition rate, width, delay and amplitude jitter.

12. BASELINE OFFSET
±2 volts

With reference to zero, the pulse train baseline may be shifted as much as ±2 volts. Whilethe specifications state thatthe maximum pulse output is ±10 volts, due to the design of the Model 139, the baseline offset will permit as much as -12 volts output for negative pulse modes. The +10 volt maximum holds true for the positive pulse modes.

External bias may also be applied, but the bias voltage plus the pulse and offset voltages shouldn't exceed ±10 volts peak as referenced to zero for 1:1 attenuation.

13. TRIGGER OUTPUT
+1.5 volts; +3 volts open circuit

The trigger output pulse is approximately 20 ns wide, and it has 5 ns/volt rise-time. $Z_O \cong 50\Omega$

14. EXTERNAL DRIVE
+1.3 volt; +15 volt

There are no rise-time restrictions on the driving signal. $Z_{in} \cong 200\Omega$

15. TRIGGER COINCIDENT PULSE

A back panel switch provides for an identical second, or double, pulse which is coincident with the trigger output pulse, and antecedent to the normal pulse. Minimum spacing between the trigger coincident and the normal pulse is 30% of the pulse width, before pulse distortion occurs.

16. OUTPUT IMPEDANCE
50 ohms

The Model 139 acts as a current source with a DC coupled output. Z_O is approximately 50Ω at high frequencies. For attenuation greater than 1:1, the attenuator is backmatched to 50Ω. The output is completely open and short-circuit fail safe, but is not intended to be operated in open circuit condition for extended periods of time

17. POWER REQUIREMENTS

105/125v, 50/60 cps, 75 watts

18. DIMENSIONS

Cabinet Mount: 6" high, 17" wide, 12" deep
Rack Mount: 7" high, 19" wide, 12" deep
Weight: 16 lbs net; 26 lbs packed; 36 lbs packed for export

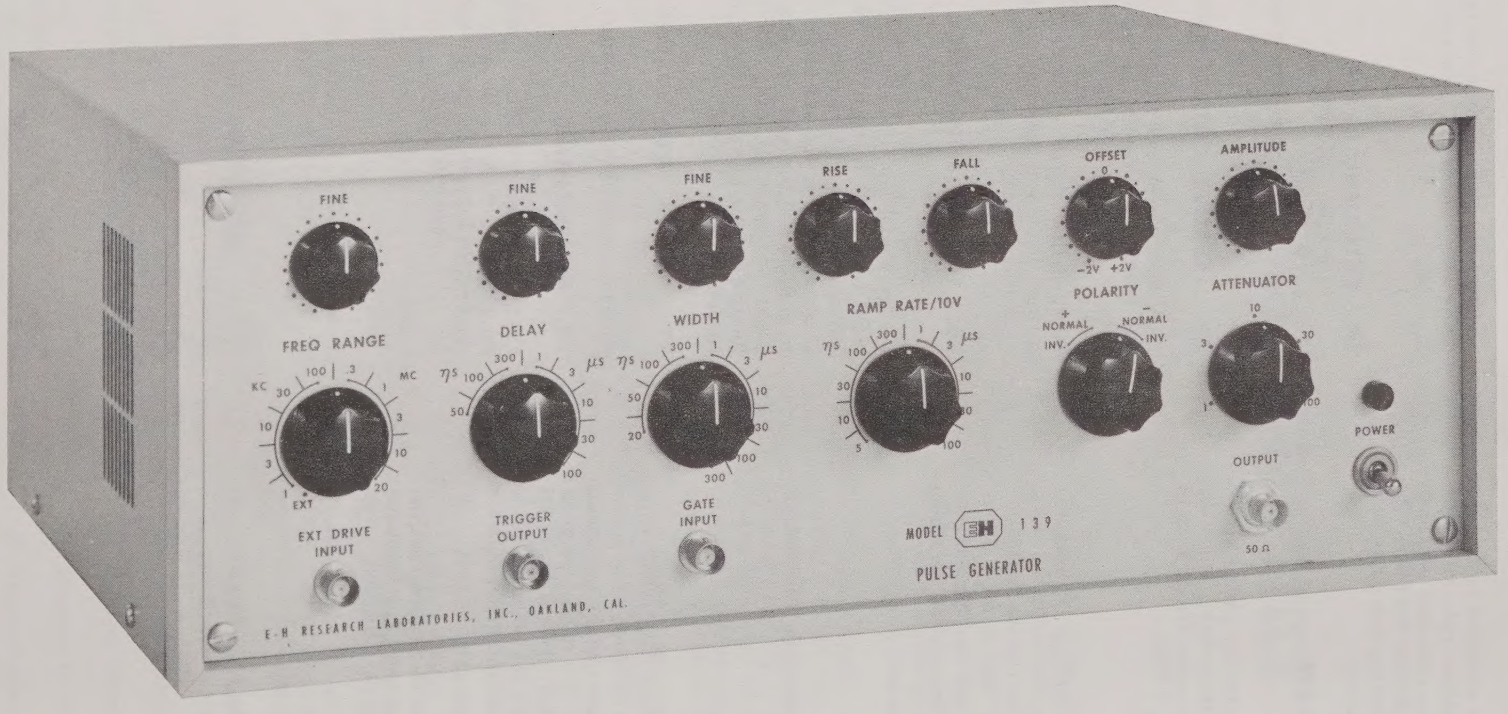


FIGURE 1 PULSE CONTROLS

II OPERATING INFORMATION

1. UNPACKING

Immediately upon receipt, carefully unpack and inspect the instrument for possible damage received during transit. If it fails to operate properly, or is damaged in any way, a claim must be filed with the carrier.

2. 220 VOLT OPERATION

The Model 139 is supplied with internal transformer power supplies. The primary windings are wired for 115 volt power line use. For use with 220 volt power lines, the transformer primaries must be rewired. Refer to the power supply schematic in this manual for the proper connections.

3. CONTROL FUNCTIONS

The location of the front panel controls are shown on the photograph on the opposite page. Their functions are briefly discussed below:

a. Freq Range

Pulse repetition rate is determined by an emitter coupled astable multivibrator which is located on the timing circuit board. The FREQ RANGE selector switch permits coarse repetition rate selection by changing the coupling capacitor. Frequency selection is in 1 - 3 - 10 steps from 1kc to 10 Mc, with high range covering 10 - 20 Mc.

The FINE frequency control, which is located above the FREQ RANGE switch, permits continuous frequency selection within any given range, with a 5% overlap to the adjacent ranges. The FINE control is a potentiometer which controls the clamp voltage applied to the collectors of Q2 and Q3 (the clock multivibrator). This provides frequency control as a linear function of rotation.

b. Delay

The delay function provides varaible control of the time between the trigger pulse and the output pulse. Coarse delay control is obtained, as with the clock multivibrator, by changing the multivibrator emitter coupling capacitance. Fine control of the multivibrator period is obtained by using a potentiometer to vary the RC time constant of the coupling network. Delay periods from 50 ns to 100 μs are available, in 1 - 3 - 10 steps.

The delay time must be less than the pulse repetition period. If it is greater, then the delay multivibrator can't turn on with each pulse from the clock multivibrator. What happens is that the delay multivibrator turns on for one pulse, and is still on for the next pulse. The result is that there won't be one output pulse for every clock pulse. Therefore, the delay time must be less than 50% of the duty cycle.

c. Width

The WIDTH control function provides variable pulse widths from 20 ns to 300 μs in 1 - 3 -10 steps, except for the 20 - 50 ns range. Pulse width, like pulse delay, is a function of the quasi-stable period of a monostable multivibrator. The coarse and fine WIDTH controls are similar in function to the DELAY controls.

The specifications of the Model 139 state that it is capable of duty cycles greater 50% and in many cases it can be increased significantly more than 50%.

However, if the duty cycle is increased much beyond 70%, pulse output tends to become very erratic. The easiest way to obtain duty cycles greater than 50% is to invert the pulse with the POLARITY selector switch.

d. Ramp Rate

The RAMP RATE control provides variable voltage ramps for pulse rise and fall times. This control has a coarse selector switch which operates in 1 - 3 - 10 steps from 6 ns to 100 μs (except for the 6 ns to 10 ns range).

Linear rise and fall time ramps are provided by charging a capacitor with a constant current. Thus, coarse control is provided by varying the capacitance, and fine control is provided by varying the current available for charging.

The coarse RAMP RATE selector switch controls both the rising and falling edges of the pulse. Individual vernier controls are provided, which are located above the RAMP RATE selector switch. The individual verniers provide as much as 3:1 difference between rise and fall times.

The pulse width must be greater than twice the ramp rate. As the ramp rate increases beyond half the pulse width, the pulse degenerates into a triangle with a notch at the apex. With a further increase in ramp rate, the pulse disappears into the baseline.

e. Polarity

The POLARITY selector switch permits the selection of one of four modes for the output pulse. The pulse output modes are illustrated in Figure 2.

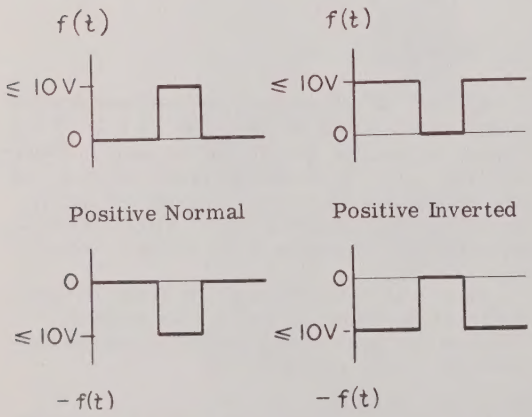


FIGURE 2

PULSE OUTPUT MODES

f. Offset

The OFFSET control, located above the POLARITY selector switch, provides a baseline offset of ±2 volts. Offset is provided, with exception as noted below, regardless of pulse polarity or amplitude.

Offset is provided by summing currents from a fixed negative source and a variable positive source. The negative current is -40 ma. Thus, for zero offset, the positive source provides +40 ma. For +2 volts offset, the positive source provides +80 ma; for -2 volts offset it provides no current.

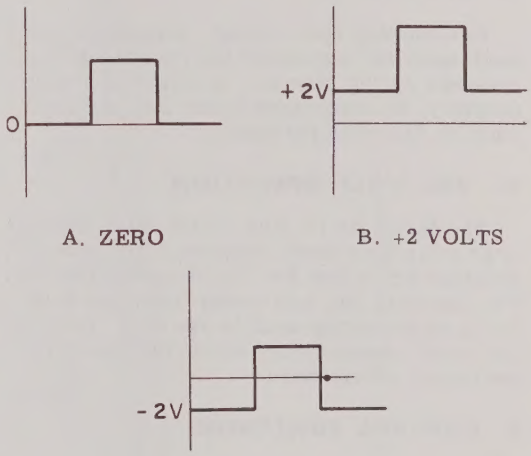


FIGURE 3

PULSE OUTPUT BASELINE OFFSET

Note that while the specifications state that the maximum output voltage for the Model 139 is ±10 volts, the offset will provide as much as -12 volts in negative pulse modes. The positive power supply is designed to provide a maximum of +240 ma. When added to a constant -40 ma, the maximum positive current is 200 ma, or +10 volts into a 50Ω load.

g. Amplitude

The amplitude control provides a continuously variable pulse output from ±3 to ±10 volts, provided the ATTENUATOR selector switch is set at "1". The amplitude control operates by

varying the maximum voltage swing across the charging capacitor C10. For a more comprehensive discussion, see Section III, THEORY OF OPERATION.

h. Attenuator

The attenuator selector switch provides step attenuation up to 300:1 (-49.5 db) of the pulse output in a 1 - 3 - 10 sequence.

i. BNC Connectors

1. Output

The BNC pulse OUTPUT connector provides an unbalanced output from the internal current sources. The Model 139 is designed to operate into a 50 ohm load, and it appears to the load as a current source in either polarity.

2. Trigger Output

The BNC TRIGGER OUTPUT connector provides a 1.5 volt trigger pulse into 50 ohms. The trigger output pulse may be used to trigger an oscilloscope, for example, or to drive another pulse generator.

3. Gate Input

If a negative pulse (-2 volts to -15 volts) is fed to the GATE INPUT, the clock multivibrator will turn off. Since the positive-going edge of gate operates synchronously. The GATE INPUT terminal has an input impedance of approximately 300 ohms.

4. Ext Drive Input

The Model 139 can be driven by another pulse generator at any frequency up to 20 Mc. Turn the FREQ RANGE selector switch to EXT and feed the driving signal into the EXT DRIVE INPUT. There is no rise time restriction on the drive pulse. The EXT DRIVE INPUT has an input impedance of approximately 200 ohms.

j. Double Pulse Mode

On the back panel of the Model 139 is a toggle switch labeled PULSE, with DOUBLE and SINGLE positions. In the SINGLE position, the pulser provides the normal pulse. In the DOUBLE pulse position, a second pulse is added to the pulse train coincident in time with the TRIGGER OUTPUT pulse. This pulse is fixed in time by the DELAY control. The time between the two pulses may be decreased to a minimum of 30% of the pulse width. If the time is further decreased, the pulse shape will deteriorate.

The trigger coincident pulse is identical to the normal pulse in polarity, rise and fall time, amplitude and width.

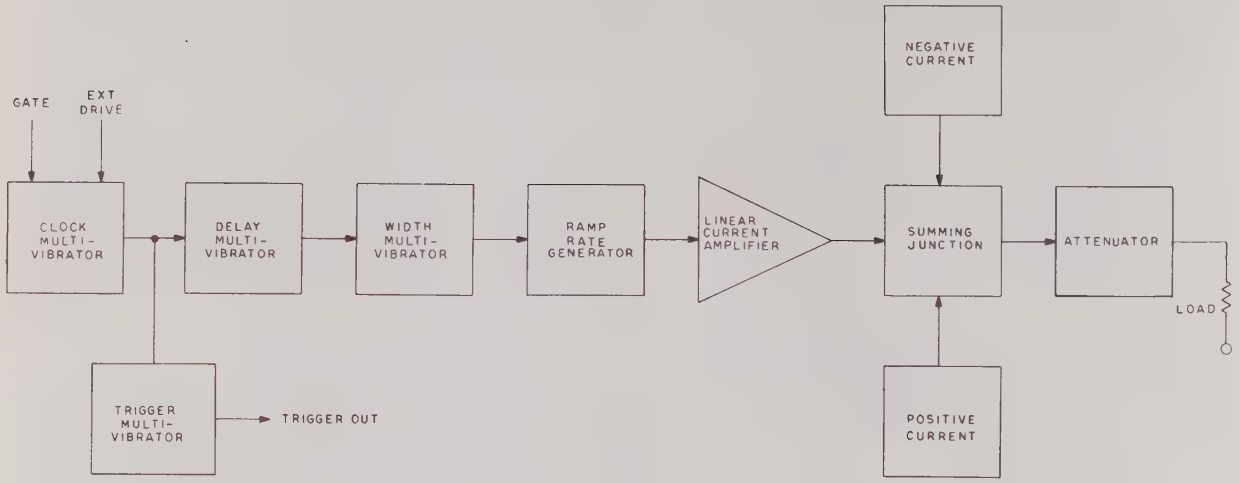


FIGURE 4

MODEL 139 BLOCK DIAGRAM

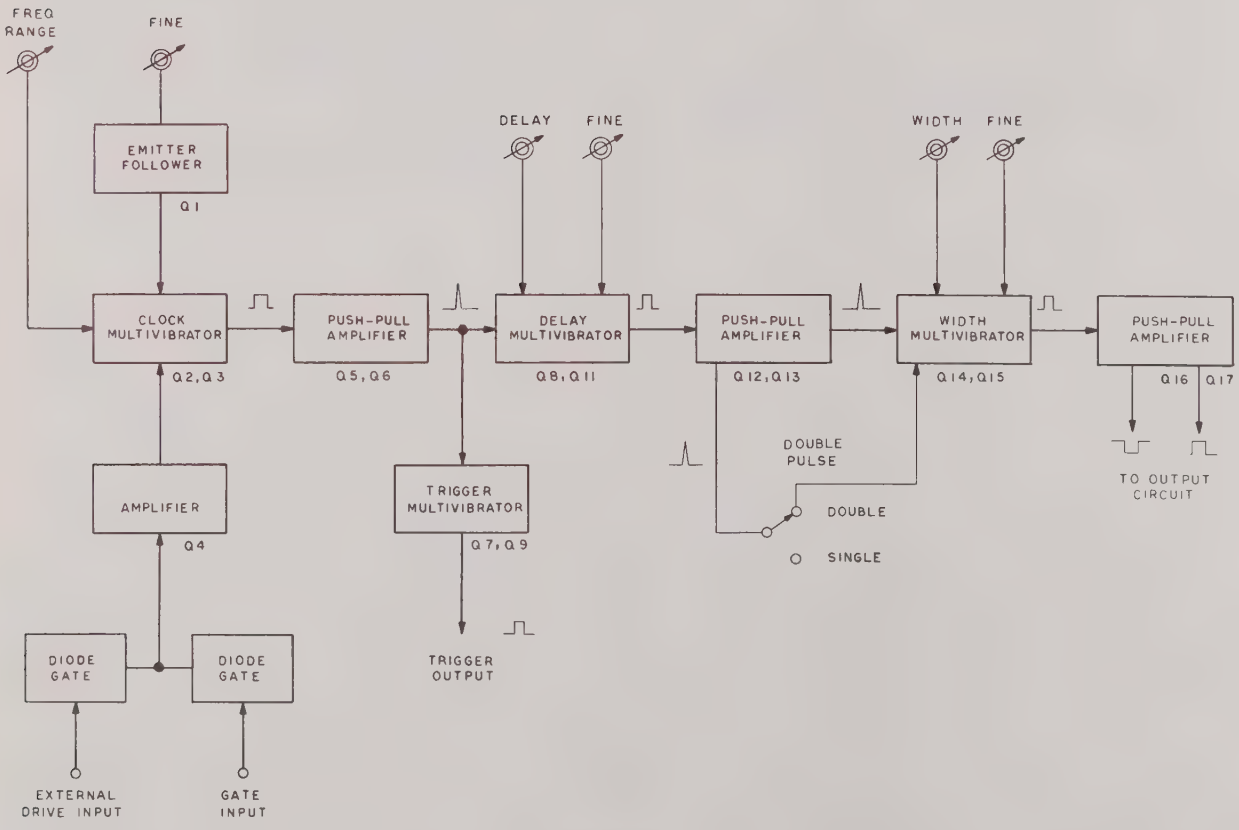


FIGURE 5

TIMING CIRCUIT BLOCK DIAGRAM

III THEORY OF OPERATION

1. TIMING CIRCUITRY

a. General

The pulse rep rate is determined by an emitter-coupled multivibrator. The period of the multivibrator is set by selecting capacitor values in a 1 - 3 - 10 sequence by the front panel FREQ RANGE control. The fine frequency control is achieved by varying the collector clamp voltage of the two transistors which comprise the multivibrator.

In the external drive position, the multivibrator is changed to a form of Schmitt trigger in which the input is the emitter of one of the transistors. Gating is achieved by disabling the multivibrator when the gating signal is present. As soon as the gating signal is removed, the multivibrator operates normally.

The output signal is taken from both sides of the free-running multivibrator and amplified through push-pull amplifiers. One of the amplifier outputs is sharply differentiated and used to trigger a one-shot multivibrator. The output trigger pulse is formed during the 20 nanosecond period of the one-shot and amplified by an emitter follower.

The differentiated amplifier output is also used to trigger the delay one-shot multivibrator. The quasi-stable period of the one-shot is determined by an RC network which is selected by the front panel DELAY controls. The pulse formed by the one-shot is again amplified by push-pull stages and differentiated to provide a positive spike.

This spike is used to trigger an identical one-shot, whose quasi-stable period determines the output pulse width. The front panel WIDTH controls select RC components which determine the one-shot period. Both polarities of the output pulse of the width one-shot are retained by push-pull amplifiers and DC coupled to the output section through a diode switching network.

b. Repetition Rate Multivibrator

The free-running multivibrator which generates the pulse repetition rate uses transistors Q2 and Q3 in a symmetrical current-mode circuit in which coarse frequency range is determined by capacitors C 201 - 214.

Vernier control is provided by varying the clamp voltage applied to the multivibrator collectors through CR1 and CR 2 and the emitter follower Q1. The variable collector clamp voltage provides frequency control, as a linear function of control rotation, as opposed to the more usual period control. To maintain proper balance in this circuit, as in other symmetrical DC coupled pairs in later stages, the coupling zeners CR 3 and CR 4 must be properly matched as noted on the schematic.

During the normal free-running operation the control transistor Q4 is saturated and does not affect the multivibrator. With the FREQ RANGE set to EXT, the biasing resistor, R 37, is switched from the +15 volt bus so that Q4 is cut off, opening the ground return to Q3 and disrupting multivibrator action. In this condition, current through R 35 places CR 21 in conduction and clamps the junction of CR 21-22 at a negative voltage equivalent to the forward drop of CR 21. Current through R 36 and CR 22 places the junction of CR 22-23 near ground potential, allowing CR 23 to conduct through R 39 and bias Q4 one diode drop negative with respect to ground.

When a positive signal into the EXT DRIVE INPUT develops sufficient potential across R 35 to cut off CR 21, the whole system up to the base of Q4 moves positive from its clamped position, sweeping the tunnel diode CR 26 past its switching point and converting slow waveforms into sharply rising wave fronts which

are passed through Q3 and Q4 to actuate the following circuitry. Note that in this mode a bias adjustment is provided for Q2 by emitter follower Q18 and trim-pot R13 so that optimum conditions may be set for fast operation at high repetition rates.

Gating is accomplished by adding the control signal to the junction of CR22-23 through diodes CR24 and CR25. A negative-going waveform into this junction cuts off the control transistor Q4 and kills the multivibrator. The turn-on edge of the gating signal finds the system in exactly the same hold-off condition at every repetition, the tunnel diode CR26 produces an identical fast-rise leading edge to drive Q4 on, and clean gating is achieved.

c. Push—pull Amplifiers

Transistors Q5 and Q6 form a push-pull buffer stage between the clock and the delay circuitry. Q12 - Q13 and Q16 - Q17 are similar buffer paris inserted for isolation between the other logic blocks of the timing system. In each case switching transients on the power supply lines are minimized by the use of symmetrical paired amplifiers.

d. Trigger Circuits

The output of buffers Q5 - Q6 is differentiated and shaped by the network L1, R44, and CR31. The positive spike generated by this network is used to key the one-shot Q7 - Q9. In the stable state Q7 is held on by the difference in emitter potentials established by CR34, and the difference in bias of Q7 and Q9 due to CR35 - 36 as against CR28. A positive spike synchronous with the clock rate is delivered to the base of Q7 through CR29 and CR30. As Q7 is driven off, its collector moves negative and pulls the base of Q9 past its cut-off point.

When Q9 goes into conduction, its emitter moves negative. Since the voltage across C15 cannot change instantaneously, the Q7 emitter is also pulled negative past cut-off, and the system will remain in its quasi-stable state until C15 charges through R46. When the emitter of Q7 again approaches its base potential, conduction through Q7 raises its collector potential and the circuit regenerates to its stable state.

The positive pulse generated at Q9 collector during the 20 nanosecond quasi-stable state is used to drive emitter follower Q10 which delivers the trigger pulse to the TRIGGER OUTPUT jack. With the trigger line properly terminated into 50 ohms, the leading edge of the pulse generated by this system shows dV/dt of 500 mv/ns for the first 500 millivolts.

e. Delay Generator

The differentiated output of the buffer amplifiers Q5 - Q6 is also used to drive the delay one-shot Q8 - Q11. The circuitry involved is similar to that used to generate the trigger pulse except that the quasi-stable period may be varied over the range 50 ns to 100 μ sec by switching in proper values from the capacitor bank C215 - C222 for coarse control. Vernier is provided by varying the resistor R202 in the charge path of the period-determining capacitor.

f. Width Generator

The positive pulse output from the delay one-shot is amplified by the buffers Q12 - Q13. Differentiating network L3, R26, and CR12 produces a positive spike from the trailing edge of the delay pulse which is used to drive the width one-shot Q14 - Q15. The configuration is similar to that of the delay circuitry, with range extended from 20 nanoseconds to 300 microseconds. Direct coupling to the buffers Q16 - Q17 retains the pulse width in both polarities. The POLARITY switch selects the desired drive polarity for the output section via the switching network R1 - R4, CR1 - CR8 on the output circuit schematic.

g. Trigger Coincident Pulse

The trigger coincident pulse is added to the pulse train antecedent to the normal pulse. Thus, the normal pulse follows the added pulse by the delay time. The normal pulse is triggered by the falling edge of the delay multivibrator output; the trigger coincident pulse is triggered by the rising edge of the delay pulse. The DELAY control on the front panel then controls the time between the two pulses.

The width multivibrator is triggered by positive pulses from the push-pull amplifier, Q12 and Q13. For the normal pulse, the output from Q13 is coupled to the width multivibrator by diode CR38. For the double pulse, an additional output is taken from Q12, and coupled to the width multivibrator by CR40. Both coupling networks are similar except that the double pulse mode is placed in operation by removing a -15 volt back bias on diode CR40. Removal of the back bias allows the signal from Q12 to trigger the width multivibrator.

OUTPUT CIRCUITRY

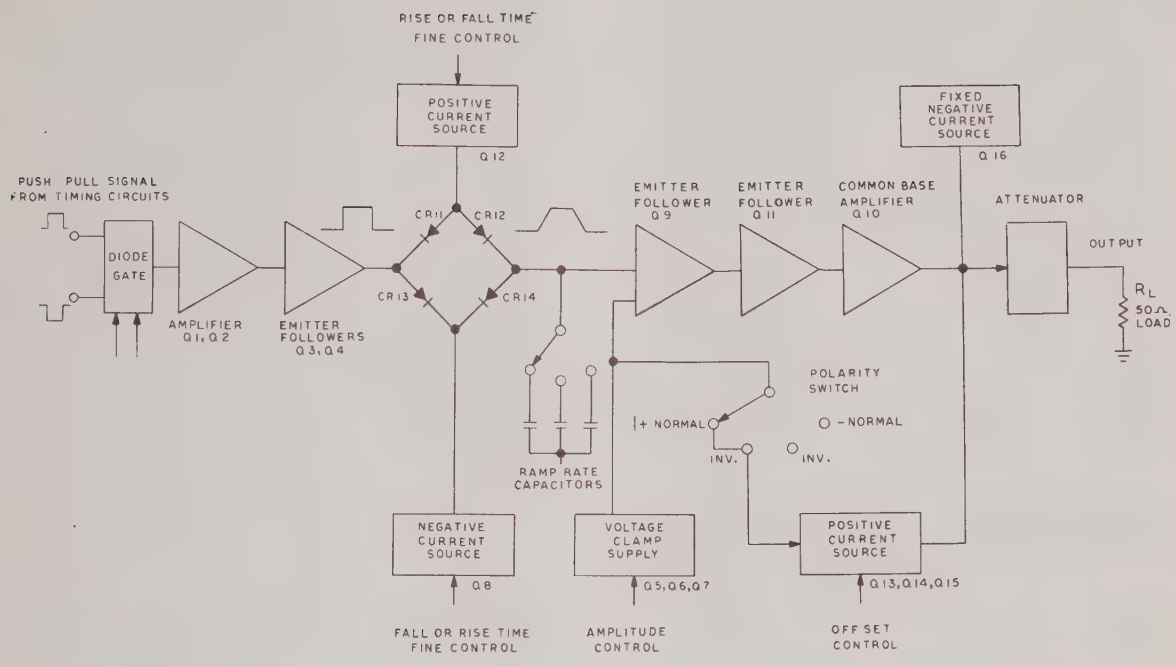


FIGURE 6

OUTPUT CIRCUIT BLOCK DIAGRAM

a. General

The Model 139 is designed to provide a current of as much as ±200 ma into a 50 ohm load. Output is provided in any of four different modes: Positive Normal, Positive Inverted, Negative Normal and Negative Inverted, as indicated in Figure 1.

If the Model 139 were to operate in only one mode, the easiest way to generate a pulse would be to switch a 200 ma current on and off. However, in order to provide four idfferent modes of operation, the Model 139 uses a current summing junction at the output terminal. The junction is provided with three current sources, as illustrated in Figure 2. See also the block diagram. In Positive Normal mode, the currents into the summing junction during the quiescent period are balanced: -40 ma, +240 ma, and -200 ma. To provide a 10 volt Positive Normal pulse into a 50 ohm load, the -200 ma current is shut off at time t_1 and the current into (and the load) is now +200 ma. The result is a +10 volt pulse. At time t_2, the -200 ma current is restored, and the current into is again zero. The -40 ma current is constant.

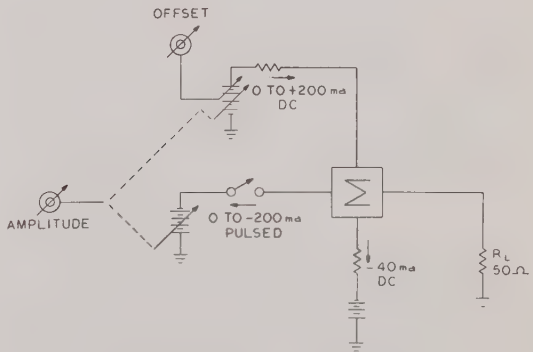


FIGURE 7

SUMMING JUNCTION BLOCK DIAGRAM

TABLE 1

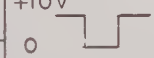
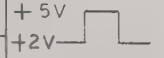
OUTPUT PULSE MODE	OUTPUT CONDITION	SOURCE CURRENT (ma) PULSE CURRENT	SOURCE CURRENT (ma) POSITIVE CURRENT	SOURCE CURRENT (ma) NEGATIVE CURRENT	CURRENT SUM Σ (ma)	OUTPUT WAVEFORM
1 POSITIVE NORMAL	QUIESCENT	− 200	+ 240	− 40	0	
	PULSE +10V	0	+ 240	− 40	+ 200	
2 POSITIVE INVERTED	QUIESCENT	0	+ 240	− 40	+ 200	
	PULSE +10V	− 200	+ 240	− 40	0	
3 NEGATIVE NORMAL	QUIESCENT	0	+ 40	− 40	0	
	PULSE − 10 V	− 200	+ 40	− 40	− 200	
4 NEGATIVE INVERTED	QUIESCENT	− 200	+ 40	− 40	− 200	
	PULSE −10 V	0	+ 40	− 40	0	
5 POSITIVE NORMAL	QUIESCENT	− 100	+ 140	− 40	0	
	PULSE + 5V	0	+ 140	− 40	+ 100	
6 POSITIVE NORMAL	QUIESCENT +2V OFFSET	− 100	+ 180	− 40	+ 40	
	PULSE + 5 V	0	+ 180	− 40	+ 140	

Table I summarizes the current flow into the summing junction. It is based on the assumption that offset is zero and output voltage is maximum (±10 volts). Note that in negative modes, the positive current source provides only the current required for the baseline offset (from 0 to +80 ma). In positive modes, the positive and negative currents are equal, exclusive of baseline offset current.

b. Negative Current Pulse

The final stage of the timing circuitry is a push-pull amplifier which provides a dual binary output: one output is the inverse of the other (See the timing circuit schematic). The timing circuit outputs are fed to a diode switching network composed of diodes CR1 through CR8. Switching is accomplished by placing either forward or back bias on appropriate diodes. Depending on the diode switching, this will connect the collector of either Q16 or Q17 to the base of either Q1 or Q2. The purpose of the diode gating network is to determine whether the output pulse is to be positive-going or negative-going. Its operation is as follows:

1. In the Positive Inverse and Negative Normal modes, line L has a positive voltage (+15v) and line K a negative voltage (-5v). In Positive Normal and Negative Inverse modes, line L has the negative voltage, and line K the positive voltage.

2. In Positive Normal mode, diodes CR5 and 6 are off due to the negative voltage on line L. CR7 and 8 are on, due to the positive voltage on K. Thus, the signal from connector M appears across R5, and is coupled to the base of Q2. In a similar manner, CR3 and 4 are off, due to the back bias voltage on line L. CR1 and 2 are on, due to the positive bias on line K. The signal from connector N appears across R6, and is coupled to the base of Q1. The gating for the Negative Inverse mode is identical.

Gating for the Positive Inverse and Negative Normal is similar, except that the bias voltages on the diodes are reversed. Thus, the signal from M is coupled to Q1 and the signal from N is coupled to Q2. The diode gating network acts as a DC actuated DPDT switch.

The output of the binary amplifier (Q1 and Q2) is taken from the collector of Q2. In the quiescent state, transistor Q2 is either on or off, depending upon the diode switching. The collector of Q2 is connected to the base leads of both Q3 and Q4. Q3 and Q4 are complementary emitter followers. When Q3 is on, Q4 is off, and vice versa. The voltage output from the emitters of Q3 and Q4 drives the diode bridge circuit (CR11, 12, 13, 14).

The purpose of the diode bridge is to switch a constant current into and out of the ramp generating capacitor, C10. The manner in which the bridge switching action is controlled by Q3 and Q4 is best understood by considering that the collectors of the transistors Q8 and Q12 are effectively clamped to the bridge output voltage by the bridge diodes CR12 and CR14. Thus, the collector of Q12 cannot become more negative than approxiamtely -18 volts (according to the amplitude clamp setting). Therefore, when the bridge drive voltage rises to about -13 volts (Q3 is on) CR11 is backbiased, and the currents flow through the bridge circuit as indicated in Figure 8

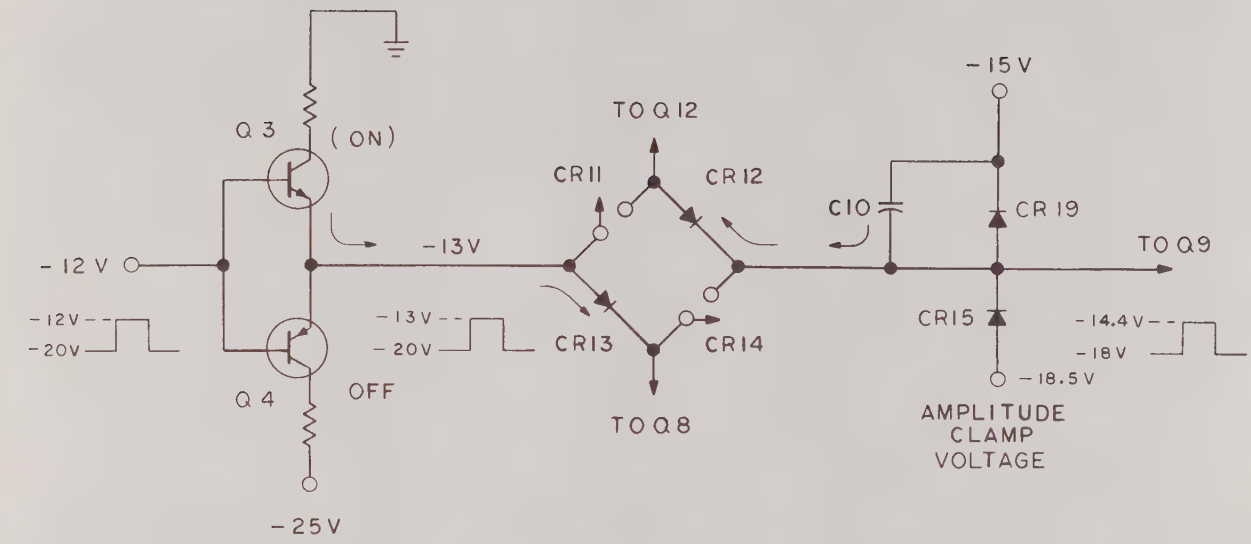
In the other state, when Q3 is off and Q4 is on, the bridge drive voltage drops to about -20 volts, and this voltage back biases CR12 and CR13. The current flow in the bridge is indicated in Figure 4B. The voltage swing of C10 is limited to approximately 3.5 volts by the two diode clamps, CR15 and CR19. For a 10 volt pulse the voltage swing is from -14.5 volts to approximately -18 volts. The lower voltage (CR15) is variable, and voltage on this clamp ultimately determines the amplitude of the pulse at the output. As the amplitude clamp voltage rises toward -15 volts, the pulse amplitude decreases. In this manner, the amplitude clamp controls the voltage swing at the output of the diode bridge (the junction of diodes CR12 and CR14).

The current into and out of the bridge is supplied by two transistors, Q8 and Q12. Q8 and Q12 are always on, and if they are considered to behave as variable current control devices, then a change in their bias voltage will change the current through the bridge. The constant current C10 provides a constant voltage ramp $dV/dt = I/C$ where I and C are constant.

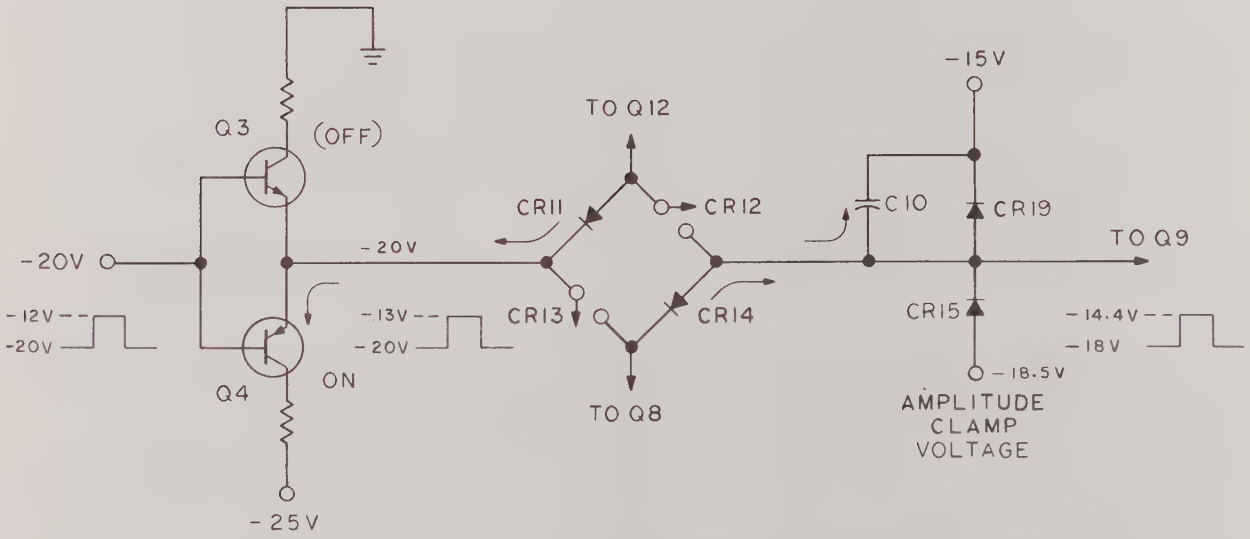
The voltage ramp drives the emitter follower Q9. This transistor has sufficient current gain to drive Q11, which in turn, drives Q10. Q10 and Q11 form a complementary pair, and operate as a linear current amplifier. Q11 is an emitter follower and Q10 is a common base amplifier. Linear current amplification permits the voltage ramps generated across C10 to control the current into the summing junction (Terminal S on the schematic).

c. Amplitude Control

The pulse amplitude is changed by varying the amplitude clamp voltage between -16.3 and -18.5 volts. Q5, Q6, and Q7 control the amplitude clamp voltage. Q5 is an emitter follower amplifier which has two functions: 1) to control the emitter voltage, and thus, the bias of Q9, and 2) to control the base current into Q6.



A. POSITIVE-GOING VOLTAGE



B. NEGATIVE-GOING VOLTAGE

FIGURE 8

DIODE BRIDGE EQUIVALENT CIRCUIT

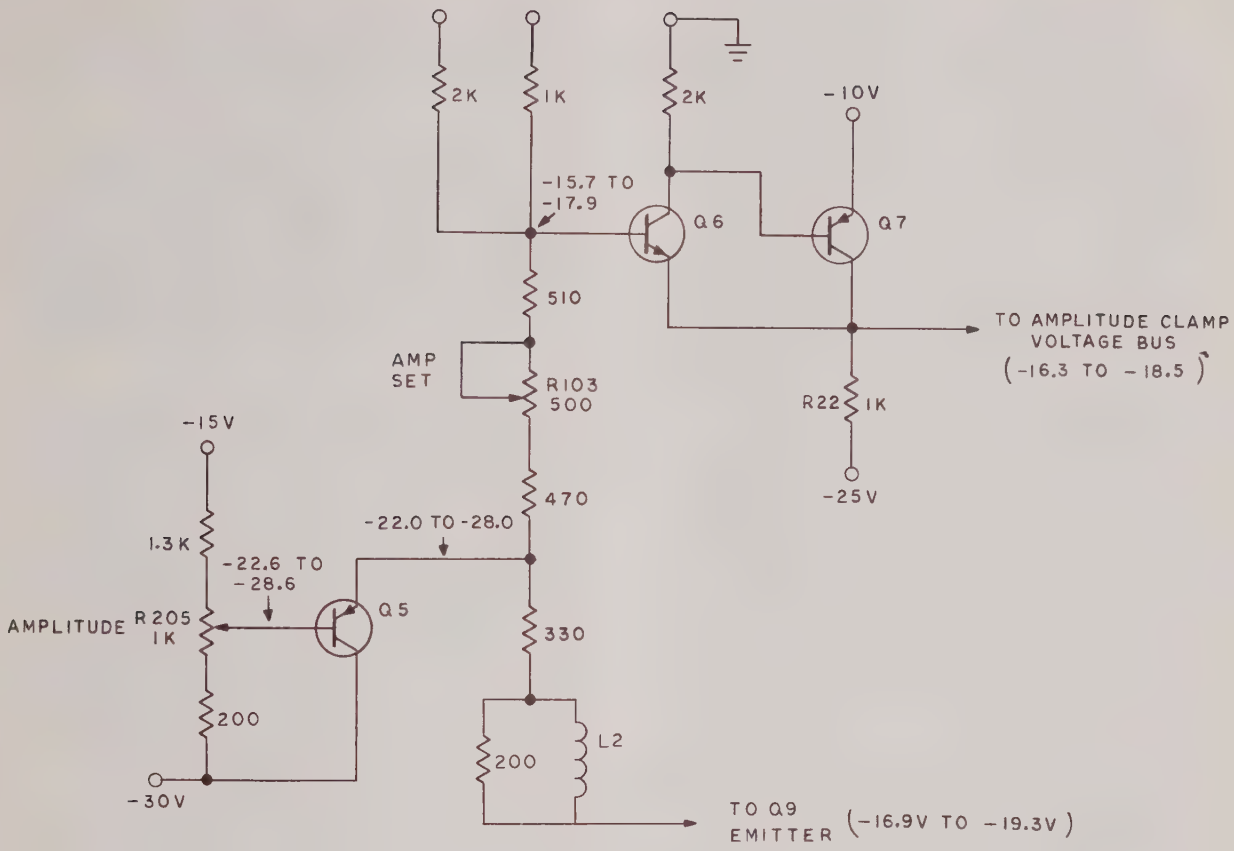


FIGURE 9

PULSE AMPLITUDE CONTROL

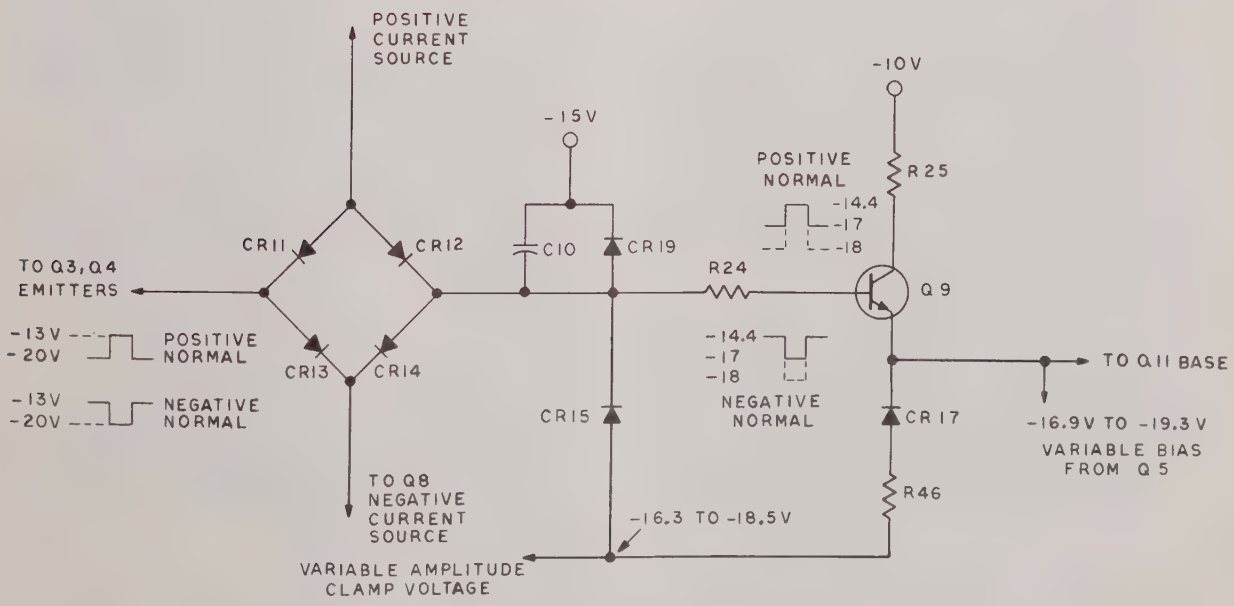


FIGURE 10 AMPLITUDE CLAMP CIRCUIT

For the following discussion, consult Figure 5. The voltage at the emitter of Q5 controls the voltage at the base of Q6 through R15, R103, and R18. The collector of Q6 is coupled to the base of Q7, and the amplitude clamp voltage is taken from the collector of Q7. A voltage change at the base of Q5 will change the amplitude clamp voltage, and, in turn, the pulse amplitude.

Q6 and Q7 form a variable shunt voltage regulator. Since the base of Q6 is at a constant voltage (between -10v and -15v) any deviation of the amplitude clamp voltage will be seen by the emitter of Q6 as a bias change. The collector of Q6 will drive the base of Q7 in a manner to compensate for the voltage change across R22.

In order to decrease the pulse amplitude, the voltage of the amplitude clamp is brought closer to -15 volts. To increase the pulse amplitude, the amplitude clamp voltage is made more negative, and for maximum pulse amplitude, the clamp voltage is approximately -18 volts.

d. Positive Current Source

The purpose of the positive current source is two fold. First, for positive pulse modes only, it supplies positive current to the summing junction that is equal in magnitude to the negative pulse current. Second, for both positive and negative pulse modes, it provides a variable current (0 to +80 ma) which is added to the negative current from Q16 for baseline offset.

The positive current is supplied by a direct coupled amplifier, Q13, 14, and 15. For positive pulses only, the base of Q14 is connected to the amplitude clamp voltage bus through S205 and R33. Thus, the amplitude clamp voltage controls both the negative pulse current and the positive current. The collector of Q14 drives the base of Q13; the collector of Q13, in turn, drives the base of Q15. The collector of Q15 is connected to the current summing junction through an LR network.

The second function of the positive current supply is to provide baseline offset current. Assume, for the discussion, that the Model 139 is operating in Negative Normal pulse mode. The positive source is disconnected from the amplitude clamp voltage, so that it provides only the current required for baseline offset. For zero offset, it provides +40 ma. When added to the fixed -40 ma current, there is no current to the load. For -2 volts offset, the positive source provides no offset current; for +2 volts offset, the positive source provides +80 ma.

Associated with the positive current source are three potentiometers, R104, R204, and R105 which are labeled ZERO SET, OFFSET. and 0 SET respectively. These are three parallel bias controls for Q14. For positive pulse modes, however, they are secondary in importance to the amplitude clamp voltage. For negative modes the amplitude clamp is disconnected.

The OFFSET pot changes the bias on Q14 in order to provide control of the baseline offset. The dynamic range of this control is determined by R28, R31, and R30 so that the output from Q15 may be varied over an 80 ma swing.

The ZERO SET is a trimmer for the Q14 bias, such that, when in positive pulse modes, the OFFSET is at zero, the ZERO SET can be adjusted so the baseline is, in fact, at zero.

The 0 SET (R105) is provided as a trimmer so that when R33 is disconnected from the amplitude clamp voltage (for negative pulse modes), the current through R32 becomes effective, and the baseline can be set at zero.

e. Fixed Negative Current Source

As shown in Table I, there is a fixed -40 ma current provided by Q16 to the current summing junction. The purpose of this source is to supply current for addition to the current from the positive source. Assuming that the algebraic sum of all other currents is zero the sum of the fixed negative (-40 ma) plus the variable positive current (0 to +80 ma) is the current available for baseline offset.

The base of Q16 is fixed at -15 volts, and its emitter is returned to the -25 volt supply through 180Ω (R41). The collector of Q16 is connected to the collector of Q15. Both Q15 and Q16 supply current to the summing junction.

f. Output Inductance Network

There are three inductors (L5, L6, and L101) between the current summing junction and the collectors of Q15 and Q16. Their purpose is to ensure that Q15 and Q16 appear to the load as a broadband constant current source.

3. POWER SUPPLY

a. General

The Model 139 has four power supplies: +15v, -15v, -25v, and -30v. Each is individually regulated to ±1 volt, with the exception of the +15 volt supply, which is factory adjusted to ±0.5v. The regulator for the +15v supply is referenced to a 6.8v Zener diode; the -15 and -25v regulators are each referenced to the +15v supply, and the -30v regulator is referenced to the -15v supply.

Power transformer T101 has two center tapped secondary windings: 60 volts and 24 volts. The 60 volt winding is rectified by two full wave rectifiers and filtered to -30 volts unregulated. This circuit supplies the power to all but the -30 volt bus.

The center tap of the 24 volt secondary is connected to the regulated -25 volt supply. The filtered output of this winding is -37 volts, and is the source for the -30 volt supply.

b. Regulators

1. +15v

Transistors Q1, Q2, Q101, and Q102 form a series regulator, in which Q101 is the pass element, and Q1, Q2 and Q102 are the feedback amplifiers. Q1 and Q2 form a single-ended differential amplifier. One input is the base of Q2, which samples the output voltage; the other input is the base of Q1, which is referenced to 6.8 volts by zener CR1. The collector of Q1 drives the base of Q102, and the emitter of Q102 drives the base of Q101.

If, for example, the regulator output voltage should drop, then the base voltage of Q2 also drops, due to the voltage regulator action of R102, R7 and R8. Since the base voltage of Q1 is constant, and the emitter of Q1 is connected to the emitter of Q2, any change at the emitter of Q2 causes an in-phase change at the collector of Q1. Thus, when the regulator output voltage drops, the collector voltage of Q1 drops below +18v. Q102 then conducts more, and the emitter voltage of Q102 moves negatively. As the base of Q101 goes negative,

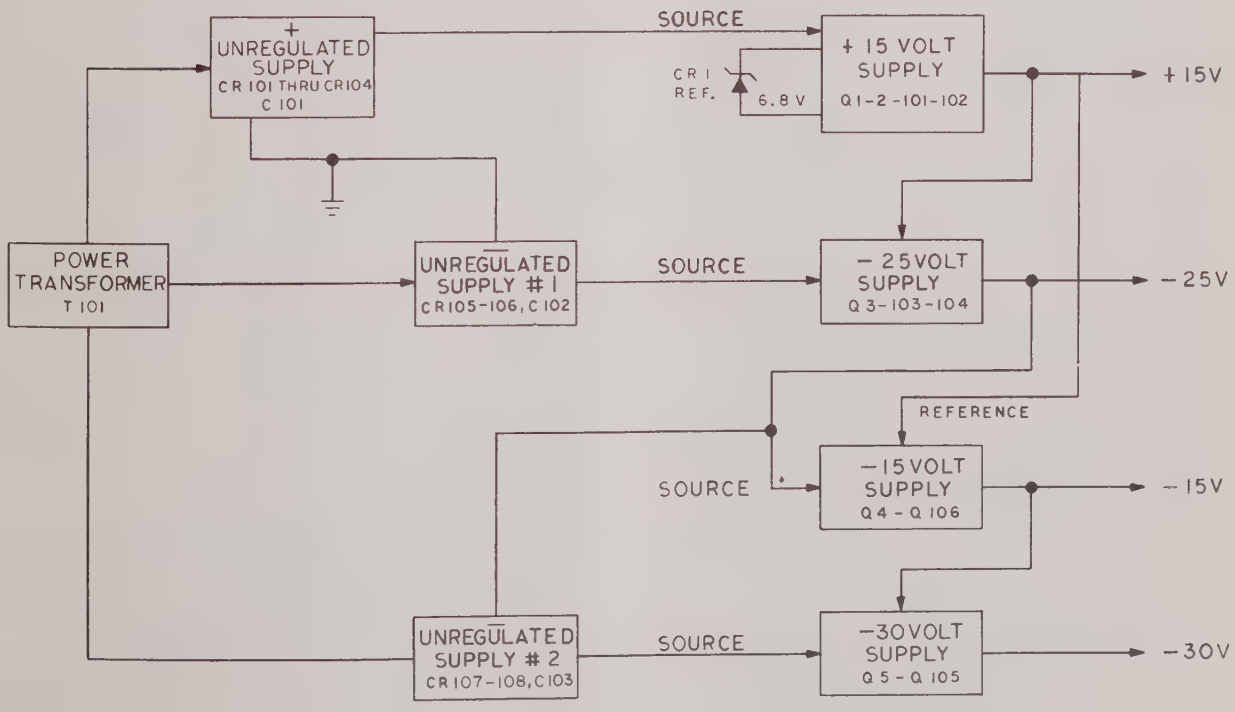


FIGURE 11

POWER SUPPLY BLOCK DIAGRAM

Q101 conducts more. Its collector voltage goes positive, which tends to correct the original voltage drop.

2. -25v

The -25v regulator operates similarly. Q103 is the pass element, and is controlled by Q104. The base of Q104 is coupled to the collector of Q3. Base bias of Q3 is similar to that of Q2: the voltage divider action of R11 and R13 (connected to +15v and -25v respectively) holds the bias voltage close to ground. Since the +15v supply is constant, any change in the -25v supply appears as a change in the bias of Q3. If the -25v supply goes positive, the base of Q3 also goes positive, and the collector of Q3 becomes more negative. When the base of Q104 turns on, the voltage across R9 goes more negative, Q103 conducts more, and the -25v supply goes negative to compensate.

3. -15v

Power for the -15v supply is taken from the regulated -25v supply. Q106 is the pass element, and Q4, which is biased in the same manner as Q3, is the feedback amplifier. Any change in the -15v supply changes the bias on Q4, and the collector of Q4 drives Q106 to compensate.

4. -30v

Power for the -30v supply is taken from the second winding of the power transformer, which is referenced to the -25v supply. The rectifier output is -37v.

Q105 is the pass transistor, and Q5 is the feedback amplifier. The operation of this circuit is like that of the -15v regulator, with the exception of the bias of Q5. Instead of the base being referenced to the +15v supply, the emitter is connected to the -15v supply. The base of Q5 is then biased between ground and -30v.

IV MAINTENANCE

1. COMPONENTS

Top quality components and precision manufacturing methods have been used in this instrument to ensure a long life with a minimum of maintenance. It should be noted that there are several factory-selected components in the Model 139 as listed below:

Schematic Reference		E-H Part No.
TIMING CIRCUIT		
CR 6, 10, 14, 19, 29, 37	Selected Pairs	374-019A
CR 3, 4	Matched Pair	374-022A
OUTPUT CIRCUIT		
CR 9, 10	Matched Pair	374-037A
CR 11, 12, 13, 14	Selected Pairs	376-039A
Q10	Selected	663-039A
Q11	Selected	663-050A

Replacement parts must be obtained either from the factory or through your local E-H representative. This will ensure your getting satisfactory replacement parts. In no case should a diode or transistor be replaced by one from a different manufacturer, unless it has been obtained from E-H.

2. COOLING

The E-H Model 139 is cooled by a fan that draws air into the instrument. The fan is lifetime lubricated and no preventive maintenance is necessary. Care should be taken to ensure that air flow is unrestricted, or the instrument may overheat.

3. TEST EQUIPMENT

The following test equipment will be required for checking the performance of the Model 139:

a. A fast rise time oscilloscope having pass band sufficient for accurate observation of 5 nanosecond pulses. (A 1 nanosecond scope, equivalent to a pass band of 350 Mc, will add approximately 0.1 ns to the 5ns switching times of the Model 139. A 100 Mc scope will make the 5 ns ramp read out at over 6 ns. Regardless of the pass band, the scope must be free from overshoot and ringing).

b. A general purpose oscilloscope of 25 Mc pass band, with high impedance, low capacity probe and DC input capability down to 0.5 volts per centimeter.

c. A pulse generator having repetition rates to 20 Mc, variable widths to 10μs, and variable output of at least 4 volts into low impedance loads.

d. An accurate multimeter.

e. A 50 ohm load having no more than 1% deviation from nominal resistance, which is capable of dissipating 2 watts and has good RF characteristics to 100 Mc.

4. PERFORMANCE CHECK

A complete performance check may be made as follows:

a. Repetition Rate

Set polarity to +NORMAL, OFFSET to zero, RAMP RATE, DELAY, and WIDTH to minimum. In single pulse mode observe the output pulse

train on a time-calibrated scope. For each position of the FREQ RANGE decade switch check repetition rate at extremes of the FINE control. There should be at least 5% overlap between ranges, with smooth and continuous variation provided by the vernier.

b. Delay

If a dual trace oscilloscope is available, the delay may be easily measured as the time difference between trigger pulse and output pulse leading edges. On all except the lowest delay range of 50 to 100 nanoseconds a satisfactory measurement may be made by triggering externally, observing the position of the trigger pulse on the sweep, and using this point as time zero in observing the output pulse. The single trace technique is subject to suspicion at low delay settings because of the possibility of shift in the oscilloscope trigger point with the change in observed waveform, even though the trigger input is unchanged. Note that the repetition rate must be decreased as delay is advanced, to ensure that the delay is no more than half the period. Spurious and erratic pulsing will occur for delays much in excess of 50% of the period.

c. Width

Observe single output pulse at full amplitude. Measurement is made at 50% of pulse height. Frequency must be decreased as width is advanced, so that the duty factor is limited to less than 50%.

d. Output

1. Amplitude: With OFFSET at zero, ATTENUATOR at 1, check output for full 10 volts into 50 ohms on all four POLARITY switch positions.

2. Attenuator: With OFFSET at zero, POLARITY at +NORMAL, AMPLITUDE at 10 volts, check that the ATTENUATOR reduces pulse amplitude approximately in the ratios indicated.

3. Offset: With ATTENUATOR at 1, AMPLITUDE at minimum, check that baseline is at zero when OFFSET is at zero. Check for minimum baseline shift of 2 volts for each polarity at extremes of OFFSET control.

4. Pulse Shape: Deviations from ideal pulse shape may be classified as aberration, droop, and non-linearity:

(a) Aberration: This term is used to describe fast excursions from the visualized straight baseline, pulse top, or ramp, usually in the form of damped oscillation. Overshoot, pre-shoot, ringing, birdies, parasitics, and blips are forms of aberration.

(b) Droop: This term is used to describe deviation of the pulse top from the ideal horizontal, and is usually expressed as a percentage of amplitude. At all settings of amplitude and ramp rate check that droop is less than 5% peak-to-peak.

(c) Non-linearity: This term is used in the sense of the definition of Independent Linearity as commonly used in the precision potentiometer field: The maximum deviation, expressed as a percentage of total voltage output, of the actual ramp characteristic from a straight reference line with its slope and position chosen to minimize the maximum deviations over the portion of the ramp between 10% and 90% of the total voltage travel.

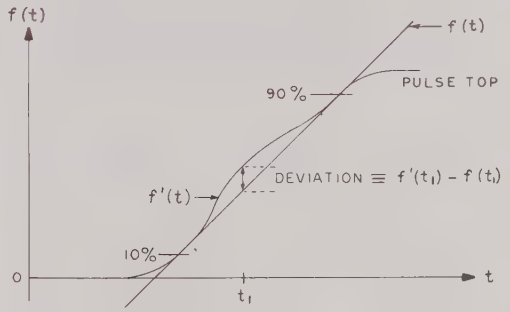


FIGURE 12

RISE TIME LINEARITY

At all settings of amplitude check non-linearity to be less than 5% for ramp rates up to 300 nanoseconds, and less than 3% for ramp rates above 300 nanoseconds.

CAUTION: Wide-band oscilloscopes are prone to overshoot, ringing and droop. The characteristics of the load and display system may affect the observed waveforms by large percentages.

e. Auxiliary Functions

1. Double pulse: Check that the double pulse switch will produce pulse pairs whose separation is variable by the DELAY control.

2. Gate: With the Model 139 clock at high rep rate, WIDTH at minimum, gate with a -2 volt, 10 μs pulse at 10 kc. Check for clean positive pulse bursts with no spruious or erratic effects.

3. External Drive: Set FREQ RANGE to EXT DELAY at minimum, RAMP RATE at minimum, WIDTH to maximum. Apply a 20 cps sine wave at 1v RMS to EXT DRIVE INPUT. Check for clean pulse output with no doubling.

Set width, delay, and ramps to minimum and apply +1v pulse at 20 Mc. Check for clean pulse output over 10 - 20 Mc range.

4. Trigger: Observe trigger output into 50 ohms at convenient rep rate. Check for 1.5 volt minimum amplitude. Width should be 20 - 30 nanoseconds at midpoint. Leading edge should take less than 5 nanoseconds to reach 1 volt amplitude.

5. SERVICING

Thorough familiarity with the functional block diagrams is necessary for intelligent servicing of the instrument. On the schematic diagrams will be found typical waveforms associated with test points at crucial points in the circuit. These test points may be located by referring to the photographs.

A few minutes spent in learning the layout and the significance of the waveforms illustrated will help you to trouble-shoot efficiently.

A suggested routine in correcting faults is as follows:

a. Confirmation of Malfunction

Be sure that there is a malfunction. Check scope, termination, and transmission line before assuming a fault in the instrument. Be sure that operating controls are set properly; that is, that the delay and width are well below the pulse period, that the attenuator is where it should be, and that the ramp rates are not so slow that no pulse can appear.

b. Visual Inspection

Make a thorough visual inspection. It is surprising how often a fault may be found without turning the set on. Look for loose or pinched wires, for charred or discolored resistors, and for components not properly seated in their sockets.

c. Power Supply Voltages

Be sure that normal supply voltages are present:

1. Adjust +15 volt bus to ±0.5 volts (R102)

2. Check -15 volt bus to ±1.0 volts (No adjustment)

3. Check -25 volt bus to ±1.0 volts (No adjustment)

4. Check -30 volt bus to ±1.0 volts (No adjustment)

Ripple on all supplies should be on the order of 5 millivolts peak-to-peak.

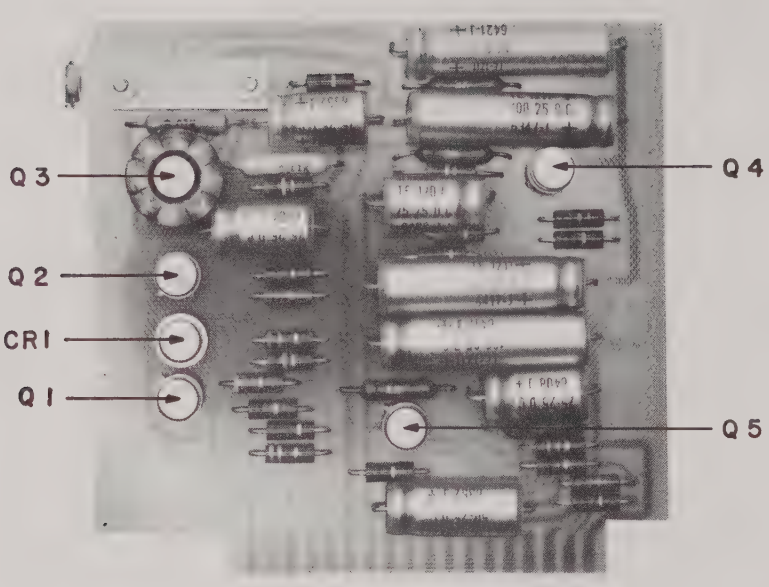
d. Block Location

From the symptoms and waveform checks, determine the area or block of malfunction. Once the DC supplies are known to be functioning properly, a convenient breakdown is between output circuitry and timing circuitry, just as the schematic drawings are broken down. The timing circuitry is required to deliver equal and opposite phase pulses to points M and N. A quick check at these points will break the problem in two, and stage-by-stage scope checks from M and N will isolate the defective block.

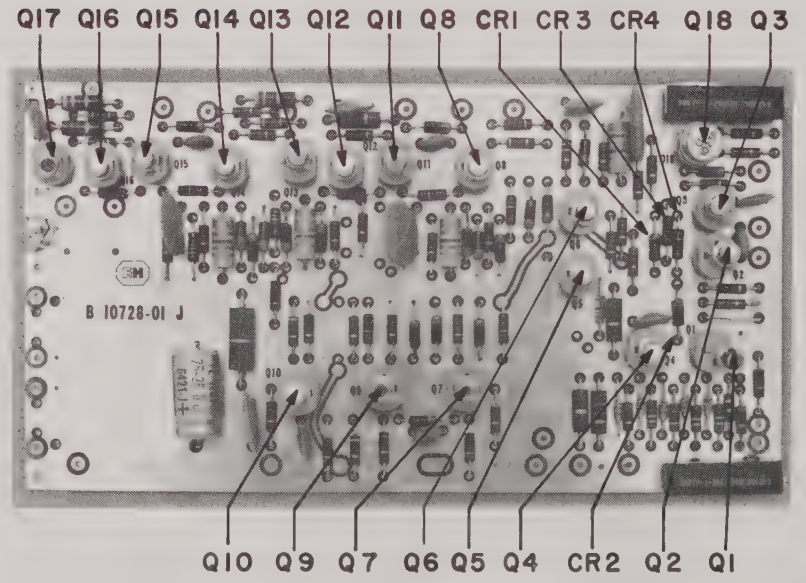
e. Component Location

Locate the defective component. Once the faulty circuit has been identified, usually by oscilloscope observation of input and output waveforms, careful measurement of DC levels and signal swings will indicate the component at fault. Throughout the circuitry, forward-conducting diodes are used to establish bias levels for transistors. Examples of this are R36/CR33, R41/CR27, and R57/CR13. A voltmeter check is sufficient to determine if these diodes are open or shorted, provided you know that forward drop across a germanium diode (e.g. 1N270, ID6-050) should be on the order of 300 to 500 millivolts. The voltage drop across a silicon diode (e.g. 1N914B) is approximately twice that of a germanium diode. Germanium devices in general (ID6-050, 2N966) are more liable to defect than silicon, and should be suspected first.

Before replacing any component, check the selected parts lists. Be sure the replacement part isn't half of a matched pair. Semiconductor devices in general show wide variation in performance from maker to maker and even from batch to batch. If you replace a factory diode or transistor with one from another manufacturer, fear the worst until performance is proven.



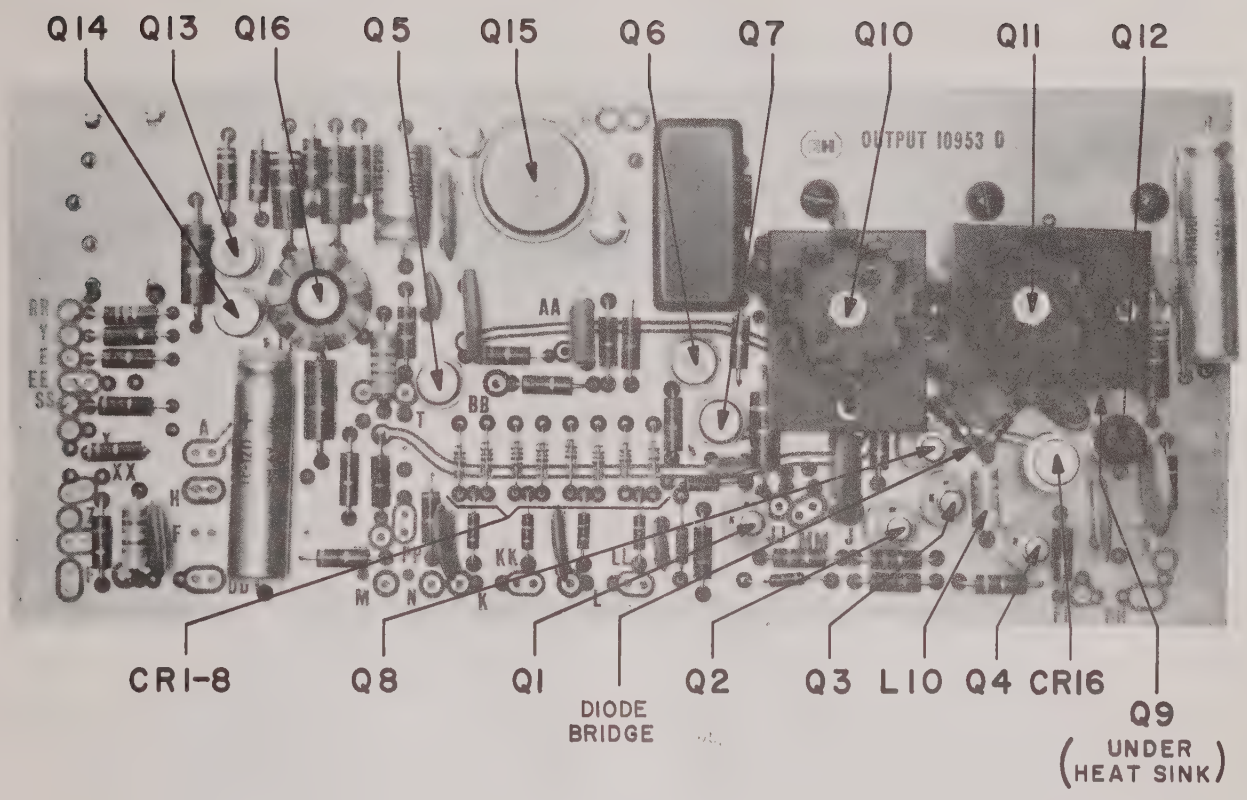
A. POWER SUPPLY PRINTED CIRCUIT BOARD



B. TIMING PRINTED CIRCUIT BOARD

FIGURE 13

CIRCUIT PHOTOGRAPHS: COMPONENT LOCATION



C. OUTPUT PRINTED CIRCUIT BOARD

V PARTS LIST

ORDERING INFORMATION

To insure your receiving the proper replacement part, please include the following information with your order.

1. Model Number and Serial Number of the instrument for which the replacement part is intended.
2. Schematic and Circuit Reference of the part.
3. E-H Part Number.

Replacement parts may be ordered through your E-H Representative or from the factory.

WARRANTY

This instrument is guaranteed to be free from defects in material and workmanship. Our obligation is limited to repairing the instrument should it prove to be defective, upon our examination, within one (1) year after the purchase date. Fuses and batteries are specifically excluded from warranty. Electron tubes, transistors, and diodes are warranted for a period of six (6) months.

For In-Warranty repair of this instrument contact E-H Research Laboratories, Customer Service Department, and provide:

1. Instrument Model Number and Serial Number
2. Full details of the nature of the malfunction

Shipping instructions, or repair information and parts, will be given you promptly.

CUSTOMER SERVICE DEPARTMENT, E-H RESEARCH LABORATORIES, INC.

163 ADELINE STREET, OAKLAND, CALIFORNIA - Phone: 834-3030, AREA CODE 415

1. MASTER SCHEMATIC

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
Capacitors		
C 201	2500 pf, 500 v, ±5%, polystyrene	326-011
C 202-3	1000 pf, 500 v, ±5%, polystyrene	326-005
C 204	250 pf, ±10%, 1 KV, ceramic	311-014
C 205-6	50 pf, ±10%, 1 KV, ceramic	311-006
C 207	1 μf, ±5%, 200 v, mylar	320-011
C 208	.2 μf, ±5%, 200 v, mylar	320-024
C 209	.33 μf, ±5%, 200 v, mylar	320-030
C 210	.1 μf, ±5%, 200 v, mylar	320-007
C 211	.02 μf, ±5%, 200 v, mylar	320-022
C 212	.033 μf, ±5%, 200 v, mylar	320-029
C 213	.01 μf, ±5%, 500 v, polystyrene	326-006
C 214	2000 pf, ±5%, 500 v, polystyrene	326-012
C 215	.15 μf, mylar	320-036
C 216	50 pf, ±10%, 1 KV, ceramic	311-006
C 217	330 pf, ±10%, 1 KV, ceramic	311-029
C 218	1000 pf, ±5%, 500 v, polystyrene	326-005
C 219	330 pf, ±10%, 1 KV, ceramic	311-029
C 220	4700 pf, polystyrene	326-018
C 221	.015 μf, ±5%, 200 v, mylar	320-031
C 222-3	.047 μf, mylar	320-032
C 224	.15 μf, mylar	320-036
C 225	.47 μf, mylar	320-035
C 226	30 pf, ±10%, 1 KV, ceramic	311-005
C 227	150 pf, ±10%, 1 KV, ceramic	311-008
C 228	400 pf, ±10%, 500 v, ceramic	311-026
C 229	330 pf, ±10%, 1 KV, ceramic	311-029
C 230	1000 pf, ±5%, 500 v, polystyrene	326-005
C 231	4700 pf, polystyrene	326-018
C 232	.015 μf, ±5%, 200 v, mylar	320-031
C 233	.25 μf, ±5%, 200 v, mylar	320-021
C 234	.07 μf, ±5%, 200 v, mylar	320-020
C 235	.025 μf, ±5%, 200 v, mylar	320-017
C 236	7000 pf, ±5%, 500 v, polystyrene	326-008
C 237	2500 pf, ±5%, 500 v, polystyrene	326-011
C 238	820 pf, ±10%, 500 v, ceramic	311-027
C 239	250 pf, ±10%, 1 KV, ceramic	311-004
C 240	50 pf, ±10%, 1 KV, ceramic	311-006
Connectors		
J 201-3	BNC, UG 1094/U	721-013
J 204	BNC, UG 909/U	721-014

Resistors: All resistors shown on the schematic, but not included on this list are 1/2 watt, ±5%, fixed carbon composition. Those resistors included in this list are also ±5%, fixed carbon composition, unless otherwise specified.

R 206	5 K Ω, 2 w, ±10%, linear taper, potentiometer	550-003
R 208	1 K Ω, 2 w, ±10%, linear taper, potentiometer	550-002
R 211	1 K, 2 w, ±10%, linear taper, potentiometer	550-002
R 218	1 K Ω, 1/4 w	595-102
Switches		
S 201	Rotary: FREQ RANGE	624-042
S 202	Rotary: DELAY	624-007
S 203	Rotary: WIDTH	624-007
S 205	Rotary: POLARITY	624-041
S 206	Special Assembly: RAMP RATE	624-029 624-020

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
S 207	ATTENUATOR Assembly	639-003
S 208	Toggle, DPDT	630-006

2. POWER SUPPLY

Capacitors		
C1	25 μf, 25v, electrolytic	316-028
C2	100 μf, 25v, electrolytic	316-035
C3, 4	25 μf, 25v, electrolytic	316-028
C5, 6	100 μf, 25v, electrolytic	316-035
C7	50 μf, 25v, electrolytic	316-037
C8	25μf, 25v, electrolytic	316-028
C9	100μf, 25v, electrolytic	316-035
C101, 102	1500 μf, 50v, electrolytic	316-045
C103	250 μf, 50v, electrolytic	316-025
C104	.1 μf, 75v	311 -014
C105	.01 μf, 600v	311-012
Diodes		
CR1	1N 3785 A, Zener	374-028
CR101-108	1N 2071	376-034

Resistors: All resistors shown on the schematic, but not included on this list are 1/2 watt, ±5%, fixed carbon composition. Those resistors included in this list are also ±5%, fixed carbon composition, unless otherwise specified.

R11	3.01 K, 1/2 w, 1%	601-018
R13	5.11 K, 1/2 w, 1%	601-076
R14	2 K, 1/2 w, 1%	618-005
R16-17	2 K, 1/2 w, 1%	618-005
R22	2 K, 1/2 w, 1%	618-005
R101	5 Ω, 3 w, wirewound	610-003
R102	1 K Ω potentiometer, linear taper, locking	545-003

Transformer		
T101	Power transformer	653-025
Transistors		
Q1, 2	CDQ 10239	663-002
Q3, 4, 5	2N 1303	663-011
Q101-106	2N 250	663-026
Miscellaneous		
B 101	Fan Motor	570-001
DS 201	Red neon pilot light assy.	510-008
F 101	Fuse 3/4 Amp., slow blow	398-017
P 101	Power Receptacle	700-018
S 204	DPST Toggle Switch	630-006
XF 101	Fuseholder	396-001

3. TIMING CIRCUIT

Capacitors		
C2	.01 μf, 600v, Ceramic	311-012
C3	.001 μf, 1 KV, Ceramic	311-010
C4	20 pf, 1 KV, Ceramic	311-002
C5	.1 μf, 75v, Ceramic	311-014
C6	.001 μf, 1 KV, Ceramic	311- 010
C7	30 pf, 1 KV, Ceramic	311- 005
C8	.001 μf, 1 KV, Ceramic	311- 010
C9	25 μf, 25v, Electrolytic	318-028
C10	.01 μf, 600 v, Ceramic	311-012
C11	30 pf, 1 KV, Ceramic	311-005
C12	.001 μf, 1 KV, Ceramic	311-010
C13	.01 μf, 600 v, Ceramic	311-012
C14	.001 μf, 1 KV, Ceramic	311-010
C15	50 pf, 1 KV, Ceramic	311-006

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
C16, 17, 18	.001 μf, 1 KV, Ceramic	311-010
C19	100 pf, Ceramic	311-007
Diodes		
CR 1, 2	ID 5-050	376-040
CR 3, 4	1N 751 A (matched pair)	374-022A
CR 5	ID 5-050	376-040
CR 6, 10	1N 753 (matched pair)	374-019A
CR 7, 8, 9	ID 5-050	376-040
CR 11	1N 751A	374-022
CR 12, 13	ID 5-050	376-040
CR 14, 19	1N 753 (matched pair)	374-019A
CR 15	ID 5-050	376-040
CR 16	1N 746 A	374-017
CR 17, 18	ID 5-050	376-040
CR 20	1N 751 A	374-022
CR 21-25	1N 914 B	376-022
CR 26	RCA 40065, Tunnel Diode	376-044
CR 27	1N 270	376-031
CR 28	ID 5-050	376-040
CR 29, 37	1N 753, Matched pair	374-019A
CR 30-36	ID 5-050	376-040
CR 38	ID 5-050	376-040
CR 39, 40	CGD 1419 (clevite)	376-046
Inductors		
L1	1.5 μh, 10%, Choke	335-001
L2, 3, 4, 5	.68 μh, 20%, Choke	335-013

Resistors: All resistors shown on the schematic, but not included on this list are 1/4 watt, ±5%, fixed carbon composition. Those resistors included in this list are also ±5%, fixed carbon composition, unless otherwise specified.

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
R1	100Ω, 1/2 w, 10%, miniature, wirewound, potentiometer	551-024
R13	2 K Ω, 1/2 w, 10%, miniature, wirewound, potentiometer	551-023
R18	560 Ω, 1/2 w	595-561
R21	330 Ω, 1/2 w	596-331
R28	560 Ω, 1/2 w	596-561
R32	330 Ω, 1/2 w	596-331
R35	1.6 K Ω, 1/2 w	596-162
R36	1.8 K Ω, 1/2 w	595-182
R37	1.2 K Ω, 1/2 w	596-122
R41	1 K Ω, 1/2 w	596-102
R58	220 Ω, 1 w	597-221
R202-3	5 K, ±10%, 2 w, potentiometer	550-003
Transistors		
Q1, 2, 3, 4	2 N 706 B	663-023
Q5, 6, 7, 8, 9	2 N 966	663-032
Q10	2 N 706 B	663-023
Q11-17	2 N 966	663-032
Q18	CDQ 10239	663-002

4. OUTPUT CIRCUIT

Capacitors		
C1, 2	.001 μf, ceramic	311-010
C3	.05 μf, 75 v, ceramic	311-021
C4	2.2 μf, 25 v, monolythic	311-019
C5	.1 μf, 75 v, ceramic	311-014
C7, 8, 9	.1 μf, 75 v, ceramic	311-014
C10	20 pf, special assembly	A-10954-01
C11	.001 μf, undipped, ceramic	312-001
C12	.01 μf, undipped, ceramic	312-003

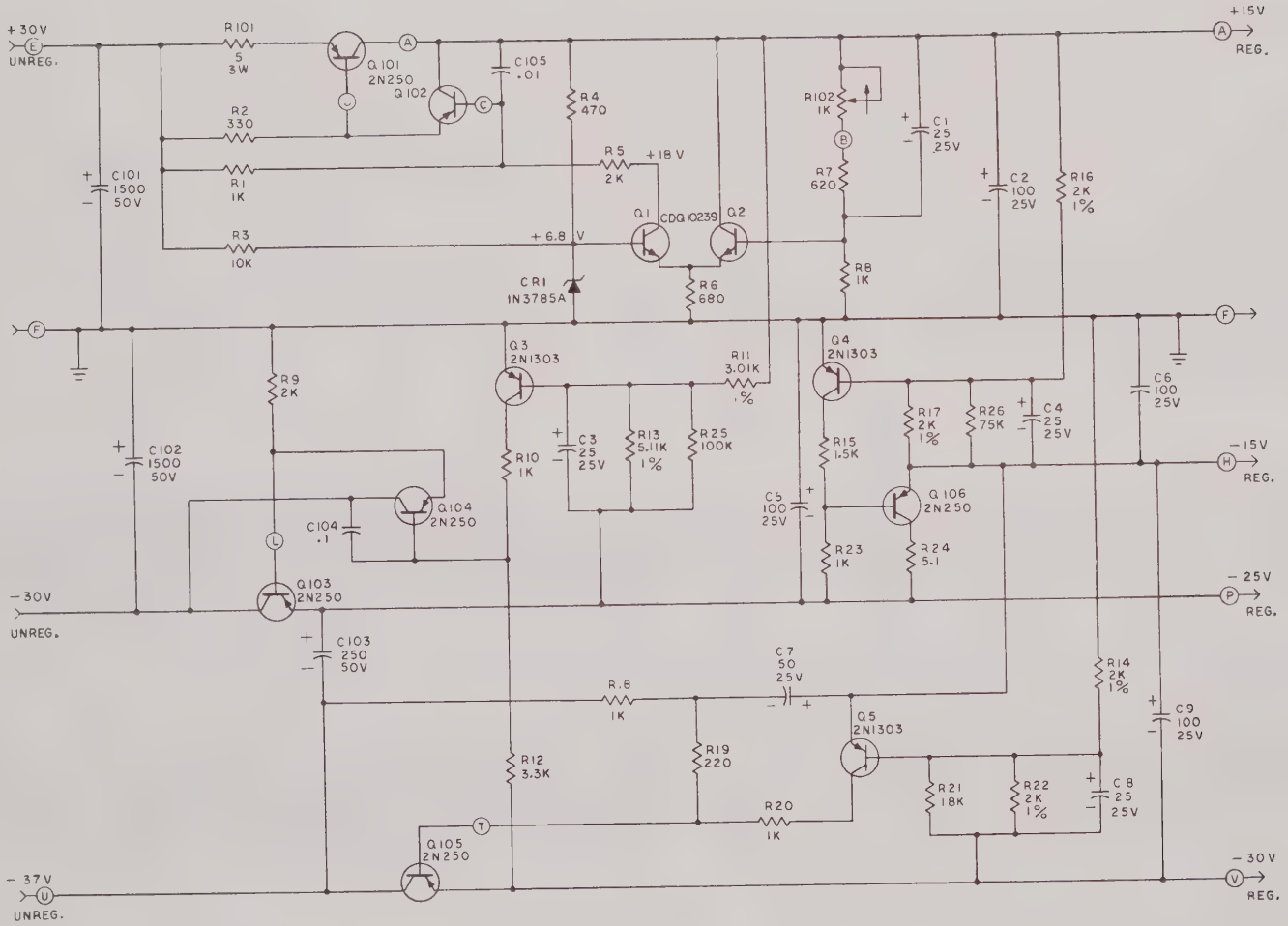
CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
C13	300 pf, special assembly	A-10952-01
C14	2.2 μf, 25 v, monolythic	311-019
C15-6	100 μf, 25 v, electrolytic	316-035
C17	25 μf, 25 v, electrolytic	316-028
C18	.1 μf, 75 v, ceramic	311-014
C19	.01 μf, 600 v, ceramic	311-012
C20	2.2 μf, 25 v, monolythic	311-019
C21-2	.01 μf, 600 v, ceramic	311-012
C23	.001 μf, ceramic	311-010
C24	.1 μf, 50 v, ceramic	311-034
C25	.001 μf, ceramic	311-010
Diodes		
CR1-8	1N270	376-031
CR 9, 10	1N759 A, Matched pair	374-037A
CR 11, 12, 13, 14	ID 6-050, Selected	376-039A
CR15	ID6-050	376-039
CR16	1N3789 A Zener	374-027
CR17	ID 6-050	376-039
CR19	ID 6-050	376-039
CR20	1N749 Zener	374-044
CR21	1N914 B	376-022
Inductors		
L1	2.2 μH miniature, choke	335-016
L2	Special Assembly	A-10995-01
L3, 4	Special Assembly	A-10956-01
L5	Special Assembly	A-10732-01
L6	Special Assembly	A-10996-01
L7	2.2 μH, miniature, choke	335-016
L8	.33 μH, miniature, choke	335-010
L101	Special Assembly	337-001

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
Resistors: All resistors shown on the schematic, but not included on this list are 1/2 watt, ±5%, fixed carbon composition. Those resistors included in this list are also ±5%, fixed carbon composition, unless otherwise specified.		
R1-4	1.3 K Ω, 1/4 w	595-132
R7	240 Ω, 1 w	597-241
R19	330 Ω, 1 w	597-231
R24	33 Ω, 1/4 w	595-330
R25	100 Ω, 1/4 w	595-101
R26	10 Ω, 1 w	597-100
R34	1 K, potentiometer	550-031
R37	430 Ω, 1 w	597-431
R38	180 Ω, 1 w	597-181
R40	10 Ω, 1 w	597-100
R41	180 Ω, 1 w	597-181
R46-7	200 Ω, 1/4 w	595-201
R48	10 Ω, 1/4 w	595-100
R49	30 Ω, 1/4 w	595-300
R50	200 Ω, 1/4 w	595-201
R103	500 Ω, ±10%, 1/2 w, locking potentiometer, linear taper	545-015
R104	10 K, ±10%, 2 w, linear taper, locking potentiometer	545-006
R105	25 K, ±10%, 2 w, linear taper, locking potentiometer	545-007
R204-5	1 K, ±10%, 2 w, linear taper, potentiometer	550-002
Transistors		
Q1, 2	2N 966	663-032
Q3	2N 834	663-028
Q4	2N 966	663-032
Q5	2N 1132	663-024
Q6	CDQ 10239	663-002

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.	CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
Q7	2N 1132	663-024	Q12	2N 1143	663-006
Q8	2N 834	663-028	Q13	CDQ 10239	663-002
Q9	2N 2369	663-009	Q14	2N 1302	663-016
Q10	2N 2950	663-039	Q15	PADT - 50	663-005
Q11	SM 2056	663-050	Q16	CDQ 10239	663-002

RECOMMENDED SPARE PARTS LIST
E-H MODEL 139 PULSE GENERATOR

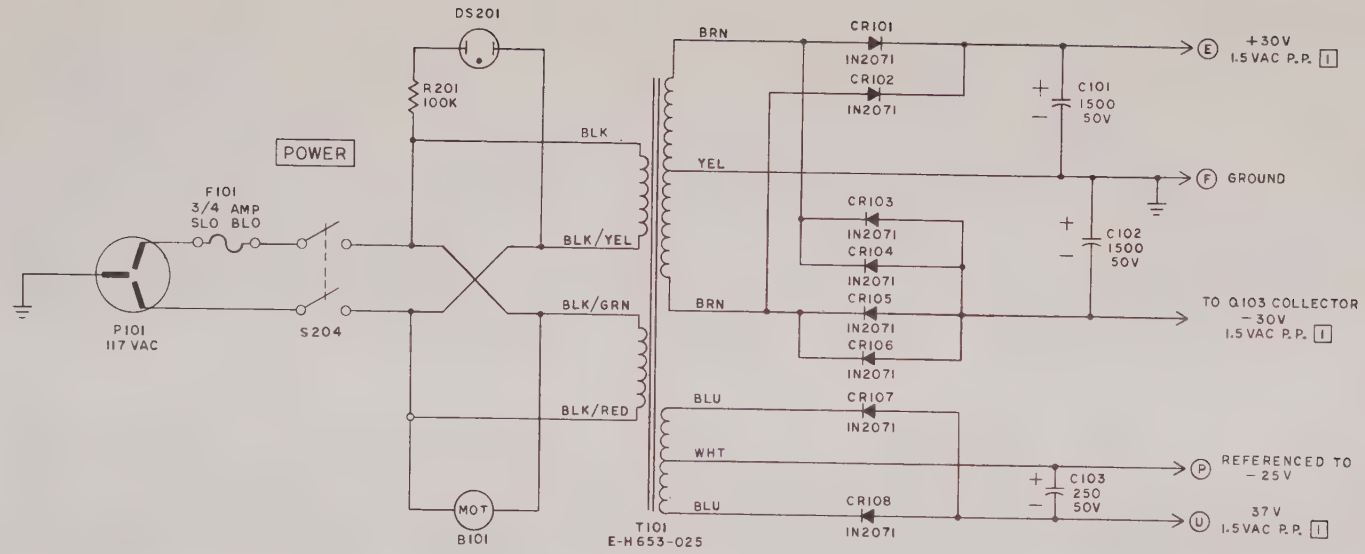
E-H Part No.	Description	Qty. Per Unit	Qty. Recommended
376-031	Diode 1N270	8	2
376-039	Diode ID6-050	8	2
376-034	Diode 1N2071	8	2
374-037	Zener 1N759A	2	1
374-028	Zener 1N3785A	1	1
374-027	Zener 1.5M10Z10	1	1
374-017	Zener 1N746A	1	1
398-017	Fuse 3/4 Amp S.B.	1	1 box
663-016	Transistor 2N1302	2	1
663-011	Transistor 2N1303	3	1
663-026	Transistor 2N250	6	1
663-032	Transistor 2N966	3	1
663-028	Transistor 2N834	2	1
663-024	Transistor 2N1132	2	1
663-002	Transistor CDQ10239	4	1
663-009	Transistor 2N2369	1	1
663-039	Transistor 2N2950	1	1
663-050	Transistor SM2056	1	1
663-006	Transistor 2N1143	1	1
663-005	Transistor PADT-50	1	1



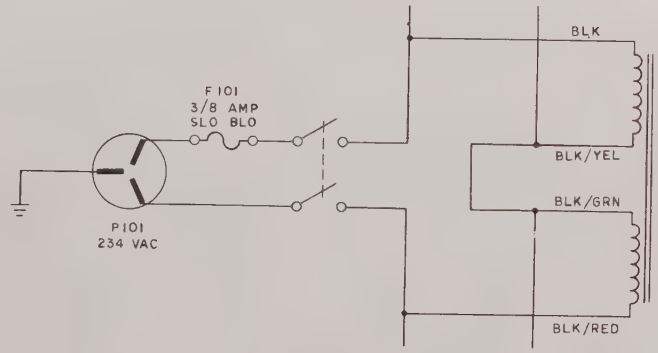
NOTES:

1. ALL RESISTANCE IN OHMS
2. ALL RESISTORS 1/2W, 5%
3. ALL CAPACITANCE IN MICRO-FARADS
4. ○ DENOTES CONNECTION ON P.C.BD.
5. Q3, REQUIRES HEAT SINK. E-H490-018

POWER SUPPLY REGULATORS SCHEMATIC



234 VOLT OPTION



NOTES:

1. [1] DC VOLTAGES TAKEN AT LINE OF 117 VAC WITH 20,000 OHM VOLT METER
2. ◯ DENOTES PIN NUMBER ON P.C. BD.

POWER SUPPLY RECTIFIER SCHEMATIC

REVISIONS						
LTR	REVISION	DATE	DRAWN	CHK'D	APPV'D	E.O.
J	DELETED PULSE MODE	2/15/65	R.S.	[illegible]		65-19
K	PIN Y WAS S	2/25/65	R.S.	[illegible]		65-29
L	PIN Z WAS U	9/24/65	R.S.	[illegible]		65-50

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B-10728-01

+14.3V
+13.5V
10 μs

+1.4V
0v
-1.4V
10μs

TO S201 C1
EXT DRIVE BIAS

+15V (A)
-15V (H)

R1 100
R2 240 (B)
R3 1K
R4 [illegible]
R5 10K
R6 1.5K
R7 220
R8 220
R9 2K
R10 1.5K
R11 330
R12 100
R13 2K
R14 750
R15 2K
C1 .01
C2 .01
C3 .001
C4 20PF
C5 .1
C6 .001
CR1
CR2
CR3 (1)
CR4 (1)
CR5
Q1 2N7068
Q2 2N7068
Q3 2N7068
Q4 2N7068
Q5
Q6
Q7
Q9
Q10 2N70
Q18 CDQ10239

TO S201 A & B ROTOR (P)
TO S201 C ROTOR (S)
TO S201 E ROTOR (U)
(F)

L1 1.5μh
R42 1K
R43 1K
R44 200
CR30
CR31
CR32

R35 1.6K 1/2W
CR21 IN914B
R34 51
CR22 IN914B
R36 6.8K
CR23 IN914B
CR24 IN914B
CR25 IN914B
CR26 RCA-40065
CR27 IN270
C14 .001
R45 3K
R46 2K
R47 750
R48 3K
R49 200
CR34
CR29 (2)
C15 50 PF
CR28
R50 220
CR37 (2)
CR35
CR36
R53 220
R51 2K
R52 1.2K
R54 3K

+15
R61 22Meg
C19 100pf
R37 4.2K 1/2W
R38 100K
R39 15K
R40 220
R41 1K 1/2W

(E) (Z) (R) (Y)
TO S201D ROTOR

R218 1K
S209
SINGLE CYCLE
EXT DRIVE INPUT
GATE INPUT

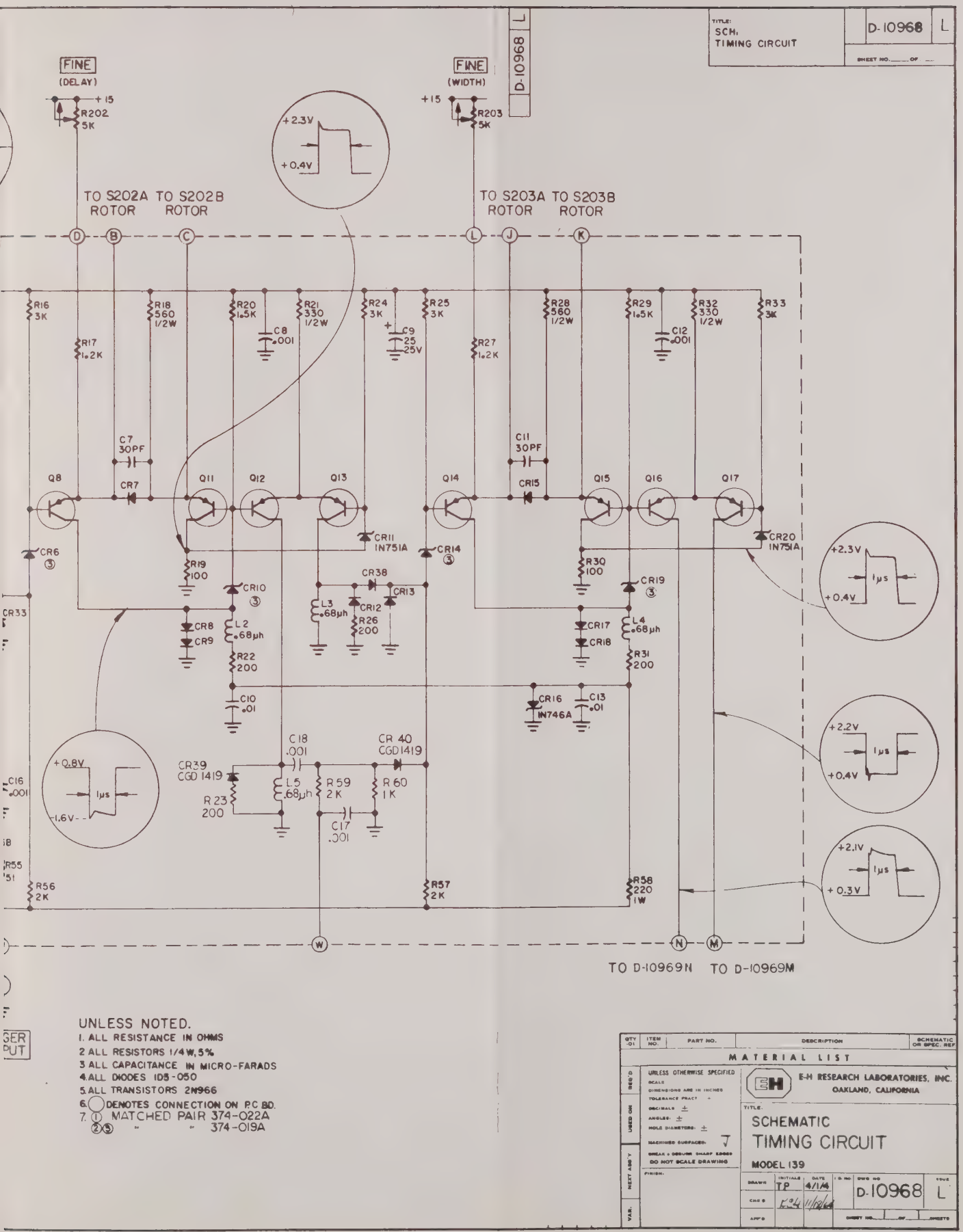
+3.3V
0v
22ns

TRIG OUT

CONDITIONS FOR WAVEFORMS:

FREQ 100 KC
DELAY 1μs
WIDTH 1μs
RAMP RATES 100ns
OFFSET 0v
POLARITY POS. NORM.
AMPLITUDE +10V
SCOPE: 30 MC (TEK, 541/L)

R	Q	C	CR	L
61	18	18	40	5


TITLE:
SCH.
TIMING CIRCUIT
D-10968
L
SHEET NO. OF
D-10968 L
FINE
(DELAY)
+15
R202
5K
FINE
(WIDTH)
+15
R203
5K
+2.3V
+0.4V
TO S202A ROTOR
TO S202B ROTOR
TO S203A ROTOR
TO S203B ROTOR
D
B
C
L
J
K
R16 3K
R17 1.2K
R18 560 1/2W
R20 1.5K
C8 .001
R21 330 1/2W
R24 3K
C9 25 25V
R25 3K
R27 1.2K
R28 560 1/2W
R29 1.5K
C12 .001
R32 330 1/2W
R33 3K
C7 30PF
C11 30PF
Q8
CR7
Q11
Q12
Q13
Q14
CR15
Q15
Q16
Q17
CR11 IN751A
CR14
CR20 IN751A
CR6
R19 100
R30 100
CR38
CR10
CR19
CR13
L3 .68µh
CR12
R26 200
CR8
CR9
L2 .68µh
R22 200
CR17
CR18
L4 .68µh
R31 200
C10 .01
CR16 IN746A
C13 .01
+2.3V
1µs
+0.4V
+2.2V
1µs
+0.4V
+2.1V
1µs
+0.3V
+0.8V
1µs
-1.6V
C18 .001
CR 40 CGD1419
CR39 CGD 1419
L5 .68µh
R59 2K
R60 1K
R23 200
C17 .001
R56 2K
R57 2K
R58 220 1W
W
N
M
TO D-10969N
TO D-10969M
UNLESS NOTED.
1. ALL RESISTANCE IN OHMS
2. ALL RESISTORS 1/4W, 5%
3. ALL CAPACITANCE IN MICRO-FARADS
4. ALL DIODES 1D5-050
5. ALL TRANSISTORS 2N966
6. ◯ DENOTES CONNECTION ON P.C. BD.
7. ① MATCHED PAIR 374-022A
②③ " " 374-019A
QTY
ITEM NO.
PART NO.
DESCRIPTION
SCHEMATIC OR SPEC. REF
MATERIAL LIST
UNLESS OTHERWISE SPECIFIED
SCALE
DIMENSIONS ARE IN INCHES
TOLERANCE FRACT ±
DECIMALS ±
ANGLES: ±
HOLE DIAMETERS: ±
MACHINED SURFACES
BREAK & DEBURR SHARP EDGES
DO NOT SCALE DRAWING
FINISH
E-H RESEARCH LABORATORIES, INC.
OAKLAND, CALIFORNIA
TITLE
SCHEMATIC
TIMING CIRCUIT
MODEL 139
DRAWN TP 4/1/64
CHK'D
APP'D
D-10968
L
SHEET NO. OF SHEETS

REVISIONS						
ISSUE	REVISION	DATE	DRAWN	CHK'D	APPV'D	E. O.
J	R50 WAS R45	3/26/65	R.S.			
K	CR21 WAS 914A	3/26/65	R.S.	KCH		
L	ADDED R219	4/9/65	R.S.	KCH		E5-30

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ZEROSE

TO S205 DI ROTOR (R) (RR)

TO S205 F2 ROTOR (L)
TO S205 D2 ROTOR (K)
TO D-10968-M (M)
TO D-10968-N (N)

R1 1.3K 1/4W
R2 1.3K 1/4W
R3 1.3K 1/4W
R4 1.3K 1/4W
C21 .01
C22 .01
CR1 IN270
CR2 IN270
CR3 IN270
CR4 IN270
CR5 IN270
CR6 IN270
CR7 IN270
CR8 IN270
R5 62
R6 62
R7 240 1W
CR9 (10)
C1 .001
Q2 2N966
C2 .001
CR10 (10)
Q1 2N966
Q3 2N834
R13 270
Q4 2N966
R9 160
R10 180
R8 2.2K
CR20 IN749
R11 2.2K
R12 51
-25V
C3 .05
Q12 2N1143
C7 .1
R21 2K
R46 200 1/4W
-10V
-15V
R14 1.3K
C4 2.2
R16 2K (6)
R17 1K
C5 .1
Q7 2N1132
Q6 CDQ10239
L8 .33μh
CR11 (9)
CR13 (9)
Q5 2N1132
R19 330 1W
R22 1K
R50 200 1/4W
L2 A-10995
R47 200 1/4W
C23 .001
L1 2.2μh
R18 510
-30V
R20 200
R15 470
C8 .1
C9 .1
B-10953
(T) (U) (W) (AA) (BB)
R219 3.9K 1/2W
R205 1K
R103 500
AMPLITUDE
AMP SET
(J)
TO S205C ROTOR

A: -12V, 1μs, -20V
B: -12V, -20V

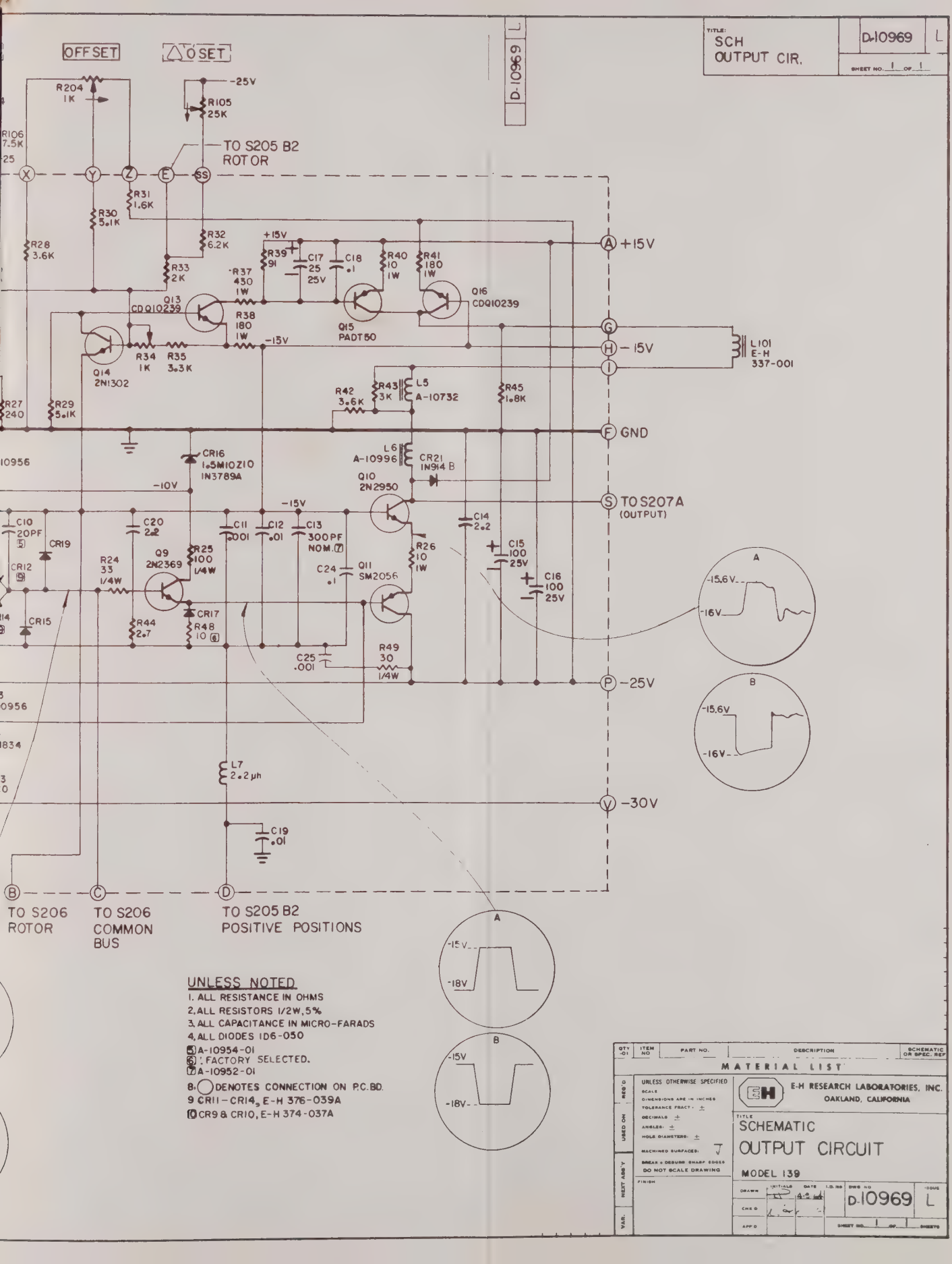
A: -13V, -20V
B: -13V, -20V

A: -14.4V, -18V
B: -14.8V, -18.4V

CONDITIONS FOR WAVEFORMS:

FREQ 100KC
DELAY 1μs
WIDTH 1μs
RAMP RATES 100ns
OFFSET 0V
POLARITY (A) POS NORM (B) NEG NORM
AMPLITUDE 10V
SCOPE: 30MC (TEK 541/L)

R	C	CR	Q	L
50	25	21	16	8



UNLESS NOTED

1. ALL RESISTANCE IN OHMS
2. ALL RESISTORS 1/2W, 5%
3. ALL CAPACITANCE IN MICRO-FARADS
4. ALL DIODES 1D6-050
5. A-10954-01
6. : FACTORY SELECTED.
7. A-10952-01
8. ◯ DENOTES CONNECTION ON P.C.BD.
9. CR11 – CR14, E-H 376-039A
10. CR9 & CR10, E-H 374-037A

MATERIAL LIST

QTY -01	ITEM NO	PART NO.	DESCRIPTION	SCHEMATIC OR SPEC. REF

UNLESS OTHERWISE SPECIFIED
SCALE
DIMENSIONS ARE IN INCHES
TOLERANCE FRACT. ±
DECIMALS ±
ANGLES ±
HOLE DIAMETERS ±
MACHINED SURFACES: ∇
BREAK & DEBURR SHARP EDGES
DO NOT SCALE DRAWING
FINISH

E-H RESEARCH LABORATORIES, INC.
OAKLAND, CALIFORNIA

TITLE
SCHEMATIC
OUTPUT CIRCUIT
MODEL 139

	INITIALS	DATE	I.D. NO	DWG NO	ISSUE
DRAWN				D-10969	L
CHK'D					
APP'D					

SHEET NO. 1 OF SHEETS

REVISIONS					
LTR	DESCRIPTION	DATE	DRAWN	CHK'D	E.O.
H	ADDED PULSE MODE	7/15/65	RS.		

PROPRIETARY INFORMATION
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INFORMATION GIVEN HEREIN MAY BE
IMPARTED TO ANY PERSON OR COMPANY
WITHOUT THE EXPRESS PERMISSION OF
E H RESEARCH LABORATORIES, INC

FINE
R206 5K

FREQ RANGE
S201
EXT 1KC
20MC 3KC
10MC 10KC
3MC 30KC
1MC 100KC
.3MC
R213 6.8K

DELAY
S202
50ns
100ns
300ns
1µs
3µs
10µs
30µs
100µs
R214 1.2K
C215 .15
C216 50PF
C217 330 PF
C218 1000PF
C219 330PF
C220 4700 PF
C221 .015
C222 .047

WIDTH
S203
20ns
50ns
100ns
300ns
1µs
3µs
10µs
30µs
100µs
300µs
C223 .047
C224 .15
C225 .47
C226 30PF

+15V

B C D J K L

P R S T U W

A F H

TIMING CIRCUIT
SCHEMATIC D-10968
INCLUDES,
FINE DELAY & WIDTH POTS
EXT DRIVE & GATE INPUT CONNETORS
TRIGGER OUTPUT CONNECTOR

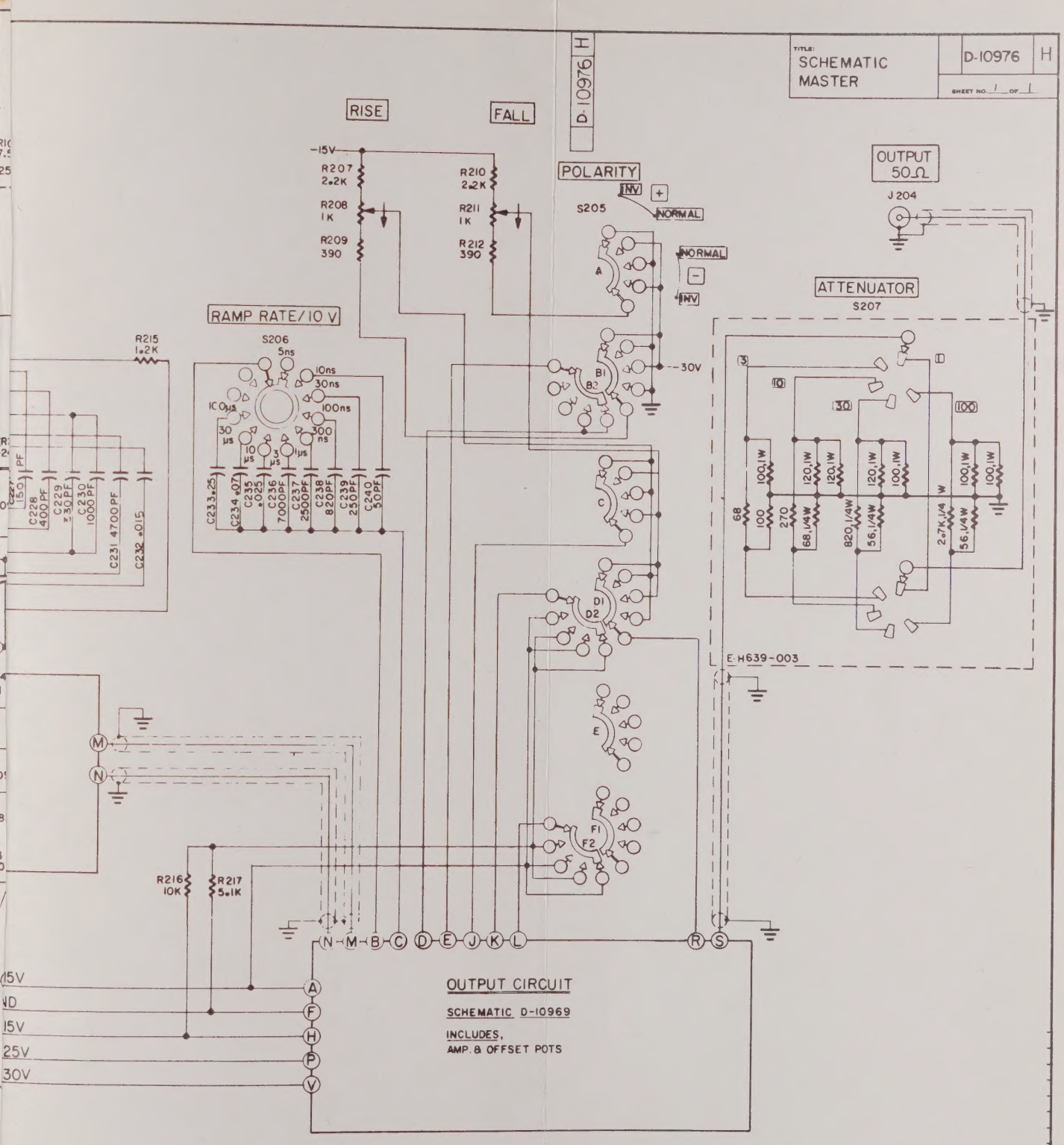
C201 2500PF
C202 1000PF
C203 1000PF
C204 250PF
C205 50PF
C206 50PF
C207
C208 .2
C209 .33
C210 .1
C211 .02
C212 .033
C213 .01
C214 .002

POWER SUPPLY
SCHEMATIC C-10966
INCLUDES,
+15V ADJUST

A F H P V

SINGLE
DOUBLE
-15

PULSE MODE
S208



UNLESS NOTED.
1 ALL RESISTORS, VALUES IN OHMS, 1/2W, 5%.
2 ALL CAPACITORS, VALUES IN MICRO-FARADS
3 "A" DECK ON SWITCHES INCLUDE NOMENCLATURE AS SHOWN ON FRONT PANEL.
4 SELECTED AT FACTORY TEST.

MATERIAL LIST

QTY -01	ITEM NO.	PART NO.	DESCRIPTION	SCHEMATIC OR SPEC. REF

UNLESS OTHERWISE SPECIFIED
SCALE
DIMENSIONS ARE IN INCHES
TOLERANCE FRACT: ±
DECIMALS: ±
ANGLES: ±
HOLE DIAMETERS: ±
MACHINED SURFACES: √
BREAK & DEBURR SHARP EDGES
DO NOT SCALE DRAWING
FINISH:

REQ'D
USED ON
NEXT ASS'Y
VAR.

E-H RESEARCH LABORATORIES, INC.
OAKLAND, CALIFORNIA

TITLE: SCHEMATIC MASTER MODEL 139

	INITIALS	DATE	I.D. No.	DWG. NO.	ISSUE
DRAWN				D-10976	H
CHK'D	RPH	2-15-65			
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